RECONSTRUCTIVE AND REPARATIVE SURGERY

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RECONSTRUCTIVE AND REPARATIVE SURGERY

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PREFACE

TEN YEARS have elapsed since the publication of the first edition of this book—a relatively short span of time, and yet a decade of rapid and profound changes in medicine and surgery effecting improvements and refinement in the art and science of plastic and reconstructive surgery The experience gained in World War II stimulated the use and evaluation of new technics in civilian practice and paved the way for further advances that later were subjected to reevaluation in the Korean conflict. The greater quiescence of recent years has provided an opportunity to digest the vast information offered by the dynamic years of the immediate past

Plastic surgery is firmly established as a separate branch of surgery the formative branch of surgery as the term plastic —popularized by E Zeis through his two scholarly works of 1838 and 1863—aptly signifies. Specialization is the present trend of medicine—justifiably so If the tree is to grow it must branch Overspecialization however is apt to lead to segregation a fact that is being more and more appreciated It impairs the versatility of the specialist, and he is likely to see only the conditions related to his specialty rather than the patient as a whole Only through application of the basic principles of general surgery to every surgical specialty can the welfare of the patient be furthered. This book is presented therefore with the hope that it may be of practical value and theoretical interest not only to the specialist of Plastic and Reconstructive Surgery but to the general surgeon as well

The book has five divisions one on general principles three on regional features and one dealing with clinical examples Division One contains general technic grafting of tissue transplantation of flaps and treatment of burns wounds and scars Divisions Two to Four demonstrate the various reconstructive principles in the different parts of the body head and neck trunk extremities other than hand and foot and hand and foot Reconstructive surgery deals mainly with the closure of defects and reconstruction in malformations hence it was considered logical and practical to carry this theme throughout the discussions on regional procedures. Thus, these chapters have been subdivided whenever possible under the headings Defects, Deformities (or Dysfunctions) The last section of the book Division Five, presents illustrative cases and their histories formerly arranged on a trial basis it has proved a worthy adjunct

to the text It has satisfied the requirements of practicality, and therefore in this second edition has been retained and expanded

This second edition has been largely rewritten Treatment and methods that have proved consistently to be efficient have been retained Others have been modified In addition, the continental literature that was inaccessible during World War II has been studied for values requiring alteration or expansion of the first edition text

The book has been greatly enlarged to include new information and many recent advances, particularly in the field of tissue transplantation, the treatment of wounds and burns, and the use of the antibiotics The sections dealing with reconstructive surgery of the face and of the extremities, particularly of the hand, have been expanded greatly. Reference has been made to some technics with which the author has had no experience but which have proved successful in qualified hands

This second edition gives the author the opportunity to acknowledge his debt of gratitude to those who have stimulated his efforts through their constructive criticism and affirmation

It is a particular pleasure to acknowledge the practical values that others have contributed to this book For those activities, and for the cordial and sympathetic attitudes that accompanied them, I am deeply grateful The drawings were made by the celebrated medical illustrators, Mr and Mrs William B McNett Mrs McNett made many from actual operations The photography throughout was the work of Mr E Richard Deats Dr David M Davis contributed the section on congenital malformations of the urethra in the male, Chapter XVIII, and Dr Harrison F Flippin, the section on antimicrobial therapy, Chapter III

I wish to express my appreciation and gratitude to my secretary, Miss Marian E Esterly, who is responsible for the painstaking task of transcription of the manuscript and the preparation of the index, and to Mr Wendell H Grenman and Mrs Florence W Brehm for editing the text

I am indebted to those authors who so graciously permitted reproduction of their illustrations, and last, but not least, to the F A Davis Company and their editorial staff for the excellent work in publishing the book

HANS MAY, M D

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DIVISION ONE

GENERAL PRINCIPLES

I

PREOPERATIVE PREPARATION, INSTRUMENTS, SUTURES, AND INCISIONS

Preoperative Preparation

A PATIENT undergoing a reparative operation requires the same careful preoperative examination and preparation as any other surgical patient. In most instances the operation is one of election, allowing time for study physical examination and laboratory work. The patient's general condition should be judged from the standpoint of risk. Detrimental factors such as respiratory infection local infection anemia hypoproteinemia and dehydration should be overcome first. (For details the reader should refer to specific subjects in the Index.) The local condition should influence the preparation and the selection of the proper operative method. A great number of patients require careful preoperative planning and imagination on the part of the surgeon. Close cooperation with other medical departments is often indispensable

In some lesions, the making of casts and moulages is requisite for a correct outlay of the operative plan Prostheses and dentures to be employed permanently can usually be prepared or made before the operation For this cooperation with the dental surgeon becomes necessary

The operating field itself is prepared in various ways The patient receives a bath the day before operation and the field itself is shaved well beyond its boundaries Even hairless skin should be shaved to remove loose scales of epidermis. (Eyebrows, however and skin to be transplanted to the face of a woman or to line cavities should never be shaved) To prepare the skin for the operation there are two methods physical and chemical

Physical Preparation of Skin. The physical preparation of the skin is done by one of the personnel whose hands are aseptically prepared It consists of gently scrubbing the skin with green (alkaline) soap and warm sterile water for ten minutes The soapy solution is frequently rinsed off with sterile water This procedure causes loosing of the epidermis and dissolving of the greasy sebaceous matter of the skin, removing detritus and organisms The skin is now dried with a towel to remove any loose epidermis, then ether is applied to dissolve remaining fatty material Finally, the entire field is washed with 70 per cent alcohol, which dehydrates the skin and is somewhat antiseptic Some surgeons prefer this method as a routine skin preparation, some prefer it for certain operations or regions It is chosen by the majority of operators for all skin-graft operations, since chemical antiseptics may harm the cells of the graft

During recent years, efforts have been made to make the surgical scrub more effective and less time-consuming The synthetic diphenol G-11 (hexachlorophene), incorporated into a bland soap, has been found to produce a marked "degerming" of the skin, much more so than soap alone (Traub, et al , Duke, et al , Blank, et al , and others) Moreover, a highly significant reduction of the permanent bacterial flora may be maintained by scrubbing every other day with this germicide, that is, cumulative action contributes to its effectiveness A popular G-11 compound is pHisoderm G-11 This is a water-miscible emulsion containing entsufon, lanolin, cholesterols, petrolatum, and 3 per cent hexachlorophene It is widely used not only for aseptic preparation of the surgeon's hands and arms, but also for preoperative preparation of the operative field Zintel and his associates have noted recently, however, that while pHisoderm provides an effective film for the surgeon's hands, the film over the operative field is broken by the knife, causing liberation of organisms Thus, in preparation of the operative field, it seems advisable to use soap, water, and alcohol instead

Chemical Preparation of Skin· The second method of preparing the skin is by chemical antiseptics Application of an alcoholic solution of 3 per cent iodine results in satisfactory disinfection To prevent irritation of the skin, the solution should be removed immediately by washing the area with a solution of from 70 to 95 per cent alcohol Another satisfactory antiseptic solution is Arnold's

Ethyl alcohol	600 0
Acetone	200 0
Mercuric chloride	1 0
Hydrochloric acid	10 0
Chrysoidin	2 0
Distilled water	q s ad 1000 0

This solution is not irritating and is therefore highly recommended Of other skin antiseptics picric acid merbromin (mercurochrome) and merthiolate may be mentioned Places particularly sensitive like the scrotum and the perineal region are disinfected with an aqueous solution of acriflavine (1 1000) Mucous membranes of the mouth, for instance are prepared by frequently brushing the teeth and applying a 3 per cent solution of hydrogen dioxide or sodium perborate. Chemical antiseptics do not influence the organisms in the mucous secretion and may harm the tissues

Instruments Suture Materials, and Sutures

Instruments The instruments needed for an average-type operation are knives (the size of the knife blade to be determined by the particu

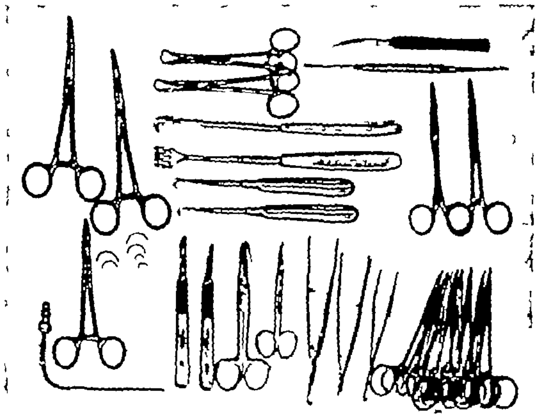


Fig. 1: Set-up of instrument table for average operation.

lar type of operation) scissors (medium-sized and small curved and straight) hemostats (ordinary size and mosquito type) retractors (with blunt or sharp hooks) forceps (plain and toothed) needles (curved and straight, with and without cutting edge) and a needle holder (Fig 1) Special types of operations may require special types of instruments (Fig 2)

Instruments are sterilized either by heat or by chemical antiseptics Since the former is more effective, it should be used whenever possible. Fine cutting instruments, however, should not be subjected to heat sterilization, since heat affects their cutting edges They are placed in a solution of formaldehyde and alcohol

Solution of formaldehyde	85
Alcohol	800
Distilled water	q s ad 1000

Suture and Ligature Material: These are classified as absorbable if they are digested by the tissues during wound-healing, and nonabsorbable if they become encapsulated

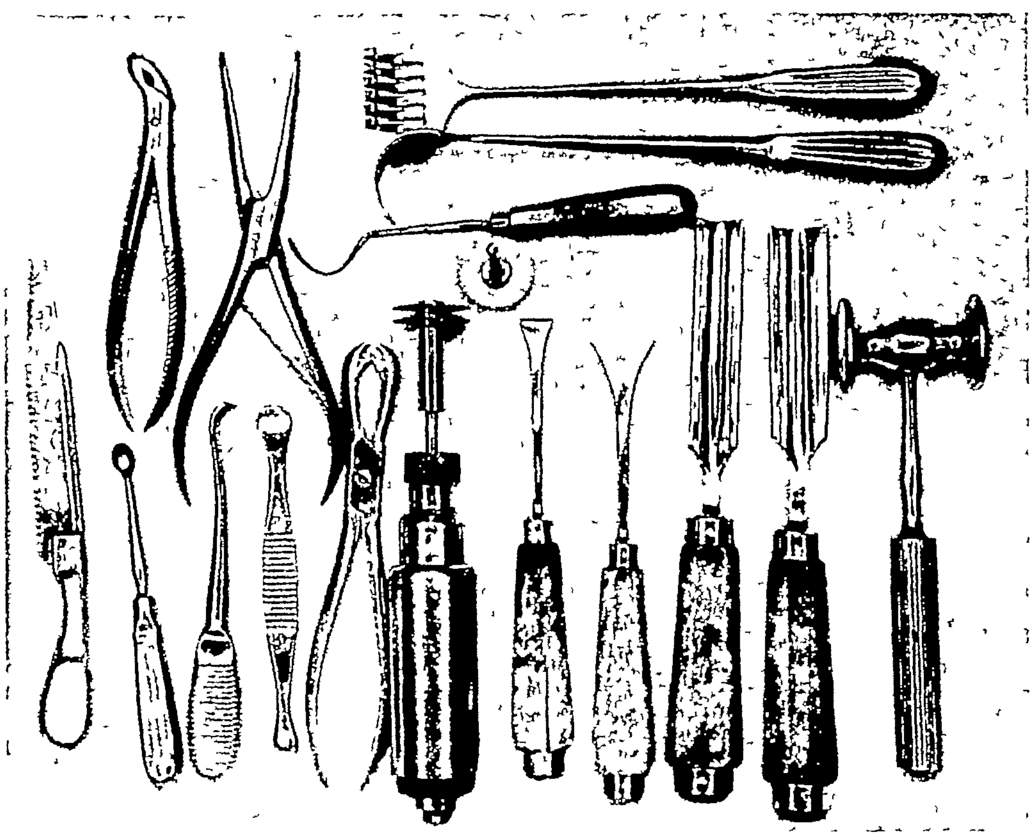


Fig 2 Set-up of additional instrument table for bone operations

Catgut Catgut is the common material for absorbable sutures Plain, or untreated, catgut is digested more quickly than chromic catgut which has been subjected to certain tanning processes and hence has acquired more resistance to the absorbing power of the tissue fluids The difficulty with catgut is the local reaction which may arise from the tissues during digestion and absorption This may lead to delayed healing and even breakdown of the tissues Furthermore, absolute sterilization of catgut without impairment of its tensile strength is not possible

Silk Silk is the most frequently used nonabsorbable material (Kocher Halsted Whipple Shambaugh Mason) It can be autoclaved or boiled. It comes braided or twisted and white or dyed black The great tensile strength of silk and its pliability allow the use of finer strands Silk sutures become encapsulated if used subcutaneously and are not irritating If embedded in infected tissue however organisms may be harbored in its interstices and the suture may become a source of infection

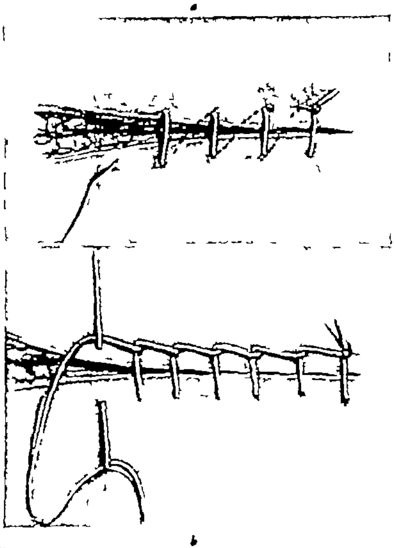


Fig. 3 Continuous suture. *a* Simple continuous running stitch. *b* Continuous single-locked stitch.

until it sloughs out or is surgically removed To lessen capillarity and increase smoothness the silk may be drawn through wax or paraffin This however makes the knot more slippery

SILKWORM GUT Silkworm gut is unspun silk. It does not consist of fibers and is smooth and strong and principally used for suturing the skin. Dermal suture a so-called artificial silkworm gut, is likewise used

as a skin suture, it is more flexible than silkworm gut and stronger than horsehair.

Nylon Nylon multifilament, a synthetic substitute for silk, is as flexible as silk In addition, it appears to be stronger (Nichols, Aries, Melick) It is less irritating when used as a skin suture, but seems to be a potent excitor of tissue reaction when it is placed within tissue (LeVeen and Barberio) It can be boiled several times without loss of its original strength

Cotton Cotton has come into vogue as suture material and for ligatures (Meade and Ochsner, Thorek, Pannett, Word and Brock) It causes

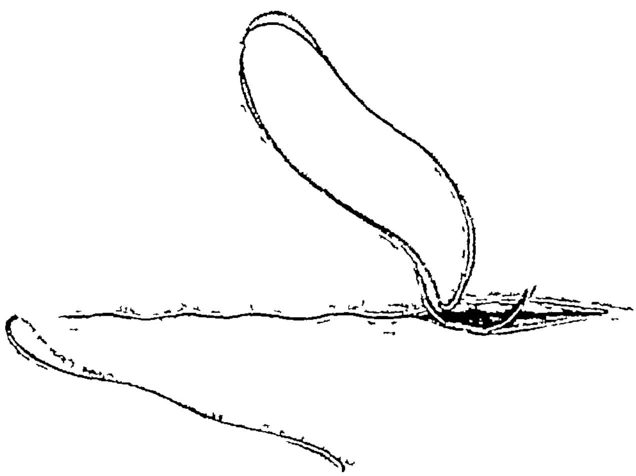


Fig 4 Cutaneous mattress suture (Halsted), used for closure of straight incisions to avoid stitch marks A fine curved needle, threaded with fine silk or wire (atraumatic needle, if available), is engaged 1 cm (3/8 inch) from wound angle and brought out at wound angle Needle is now passed horizontally through derma on one side and through derma of opposite side until entire wound is closed At opposite wound angle, needle is brought out 1 cm (3/8 inch) away from angle

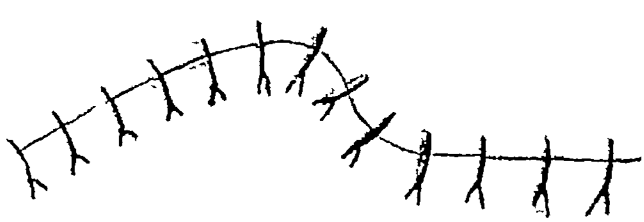


Fig 5 Interrupted sutures Stitches lie rectangularly to edges of wound

less cellular exudation but it has less tensile strength than silk it is less capillary and shows much less tendency to tissue ingrowth and is therefore less likely than silk to cause sinuses in the presence of infection It is inexpensive and can be easily sterilized

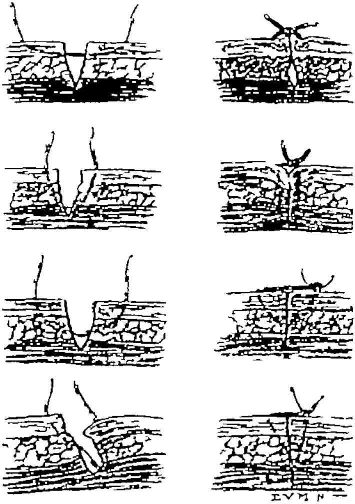


Fig. 6 Various interrupted sutures, passed correctly and incorrectly *First row* Suture not passed deeply enough, resulting in dead space beneath and uneven coaptation of skin edges. *Second row* Suture penetrating too deeply causing dimpling of wound edges. *Third row* Suture passed correctly at a distance equal to half the distance from wound edges on each side of wound. *Fourth row:* Uneven wound edges; suture including more tissue on retracted than on elevated side.

Horsehair Horsehair is also used for skin sutures It is flexible and noncapillary but it has little tensile strength

Linen Plain linen is literally linen thread derived from flax it is stronger than silk and cotton but less pliable and frays easily Pagenstecher's linen is impregnated with celluloid which makes it less capillary smoother and stronger

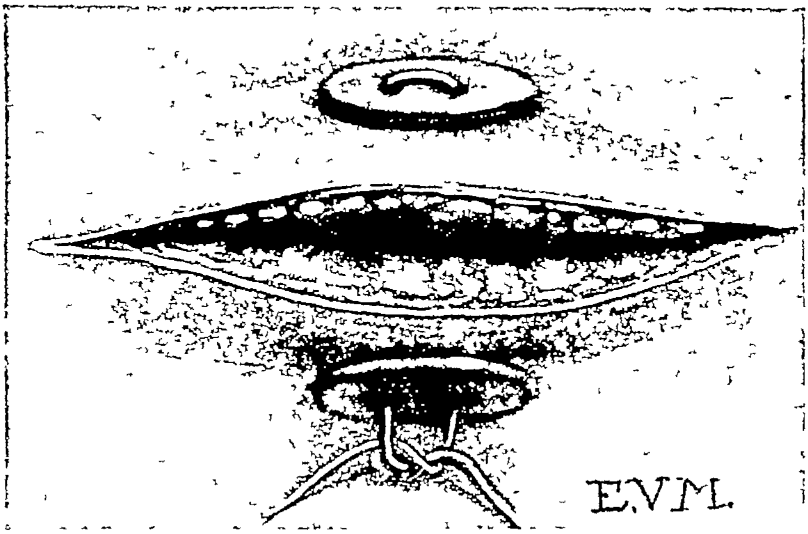


Fig 7 Relaxation suture tied over metal plate for relief of tension Buttons, rubber tubing, or rolls of gauze may also be used

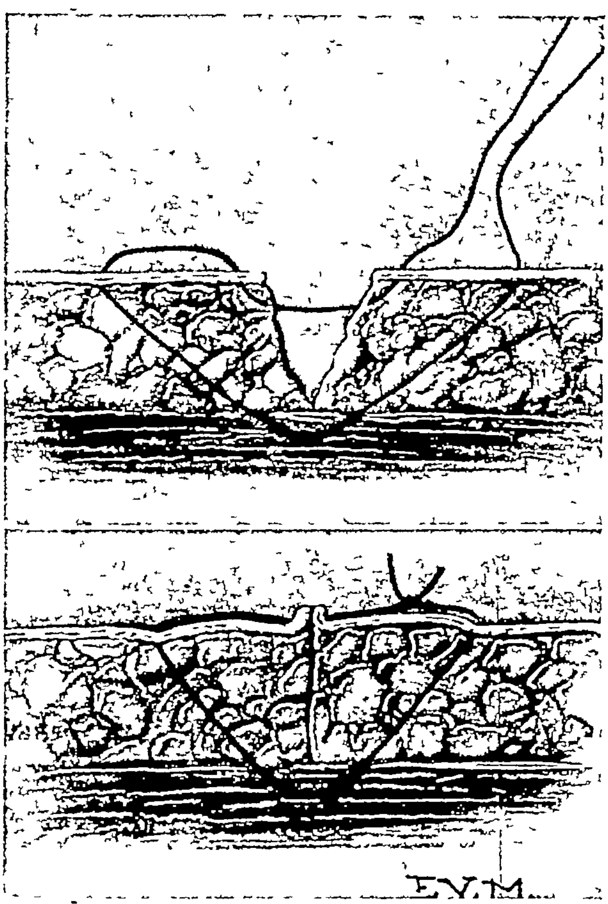


Fig 8 On-end mattress suture for broad apposition and eversion of wound edges

Wire Wire is occasionally used as suture and ligature material in reparative surgery as well as in bone surgery It comes in different calibers The rustless steel wire (an alloy of steel nickel and chromium) is smooth strong pliable and noncorrosive and hence does not irritate the tissue (Babcock) Tantalum wire seems to have the same qualities Ivy recommends brass wire for interdental wiring to immobilize the jaws and keep the teeth in occlusion this kind of wire freely lends itself to this type of work.

Sutures. Sutures are continuous or interrupted (Tauber s small monograph on this subject is very descriptive.) A *continuous* suture is a running stitch which approximates the wound edges and is tied only at the beginning and the end. The advantage is that it can be applied quickly the disadvantages are that it may hold the wound edges under uneven tension and if it tears may cause spreading of the entire wound. Various types of continuous suture are depicted in Fig 3 The continuous suture should not be used in surgery of the face. Halsted s cutaneous mattress suture (Fig 4) is of value in avoiding stitch marks (Case 17 p 870) It can be used only for closure of straight incisions In long incisions it should be used in sections

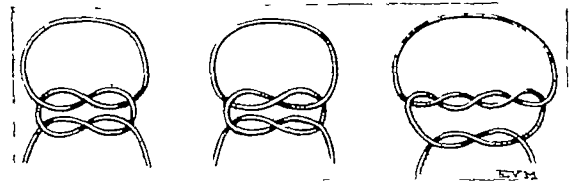
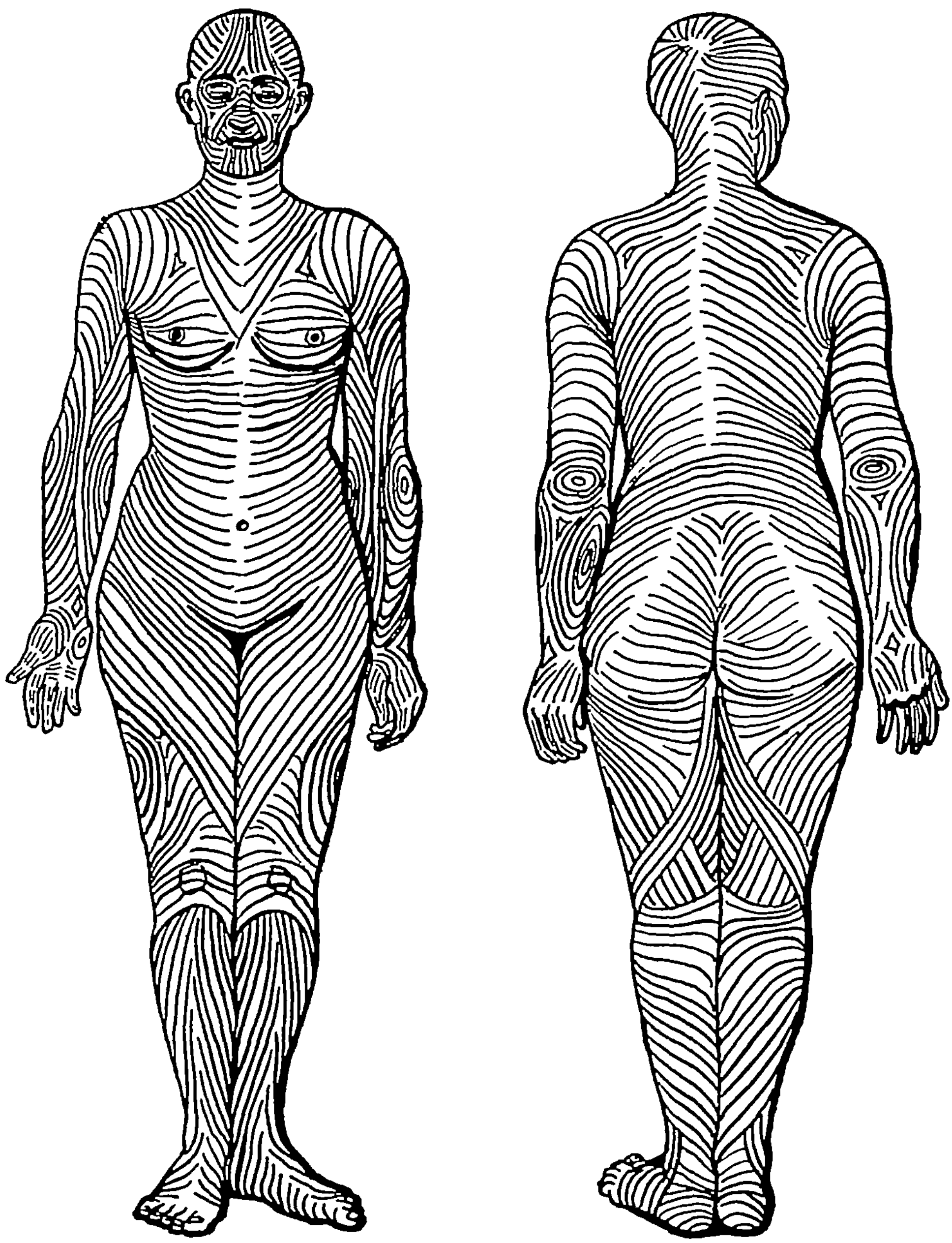


Fig. 9 Knots. *Left to right:* "Granny knot" (not to be used) reef or square knot, surgical knot.

The *interrupted* suture is the more important. The stitches should lie rectangular to the wound edges (Fig 5) The needle is passed through the skin a few millimeters from the wound edges and then through the subcutaneous tissue. The depth of the suture depends upon its width. If the suture is not passed deeply enough through the tissue a dead space may be left beneath resulting in an uneven adaptation of the skin edges, with overlapping or underlapping (Fig 6 upper row) If the suture penetrates too deeply it may cause dimpling of the wound edges (Fig 6 second row) As a rule sutures should penetrate to a distance equal to half the distance from the wound edges on each side

of the wound (Fig 6, third row) If, however, the wound edges are lying uneven to each other, the suture must include more tissue on the retracted side than on the elevated side, to correct the displacement (Fig 6, fourth row) If the wound edges are under tension, relaxation



a *b*

Fig 10 Langer's lines of cleavage of skin

sutures should be used (Fig 7). The on-end mattress suture is useful in those cases in which broad apposition and eversion of the wound edges are needed (Fig 8). It may be used alternately with ordinary sutures

Knots In tying sutures and ligatures too many loops should be avoided The simple knot forms the basis of practically all knots It consists of one twist. The reef or square knot is the one most often used in surgery It consists of a simple twist in one direction and another twist in the opposite direction It has less tendency to become untied than a granny knot, which should not be used The surgeon's knot consists of a double twist in the first part and a single twist in the second The double twist is used to cause friction and thus prevent slipping of the suture or ligature while the second knot is being tied (Fig 9)

Fig. 11 Skin incisions laid perpendicular to the action of the underlying muscles come to lie within the folds of the adherent facial skin which form at right angles to the action of the underlying muscles. (Kraissl, C. J Plast. & Reconstruct. Surg.)

Incisions

In elective incisions the incision should if possible be placed along the lines of cleavage of the skin to obtain fine line scars Langer was the first to point out the advantage of this and devised lines representing the elastic lines of the skin (Fig 10) Incisions along these would heal with fine scars The explanation was twofold (1) A scar parallel to the lines

would be inconspicuous because it resembled a line This explanation holds. (2) Pull on the wound edges would be avoided owing to the parallel directions of Langer's lines and the muscles Actually, however, as Rubin, Kraissl, and others have observed, the muscle pull tends to separate the wound edges, thus widening the scar

Facial wrinkles are the result of contracture of the underlying muscles of facial expression They lie at right angles to the direction of pull As Kraissl and Conway point out, it is evident that the wrinkles are caused by the shortening of the muscle without corresponding shortening of the skin Therefore, the skin adapts itself to this irregular mechanism by forming folds that are at right angles to the action of the underlying muscles In some regions, several muscles act in unison to produce facial expression, with the result that the skin wrinkles are in a curved line (nasolabial fold)

Kraissl offers a revised pattern for making elective incisions on the body surface (Fig 11) Where the underlying muscles are attached to the skin, as in the face, the incisions are perpendicular to the muscular action Where there is no attachment to the skin, the incisions are perpendicular to the direction of excursion of the skin produced by normal muscle pull (Blocker) Even with free grafts, particularly when placed on the face or near the joints, the incision should be made in such a manner that the marginal scars are in proper lines, in a contracture of the neck, for example, the relaxation incisions are so placed that the scars will lie horizontally, not vertically When using a full-thickness graft, the surgeon should attempt to place the skin in its new position with respect to the lines it occupied in its donor site

Anesthesia

Various types of anesthetics and anesthesia are discussed on pp 156, 463, 549

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II

SHIFTING OF TISSUE, FREE TISSUE-GRAFTING, TRANSFER OF FLAPS

REPARATIVE and reconstructive surgery is concerned mainly with closure of defects, either of the soft tissues or of the framework of the body, and the reconstruction of malformations, including the reestablishment of function and the improvement of appearance, with resulting relief of psychological handicaps The ways by which these two problems can be solved consist chiefly in tissue-shifting, free tissue transplantation, and transfer of pedicle flaps

Shifting of Tissue for Closure of Surface Defects

Shifting of skin and subcutaneous tissue is performed for the purpose of closing certain surface defects The principles involved in tissue-shifting consist in the mobilization of the tissue adjacent to the defect by thorough undermining and sliding it into the defect Its use is, of course, limited to smaller defects and only to those in which the skin surrounding the defect is freely movable Sometimes additional incisions (relaxation incisions) are necessary to facilitate the mobility of the undermined tissue In this respect, the method encroaches on some of the flap methods in which the flap is taken from the immediate neighborhood (French method) The incisions, if possible, should be placed in the direction of the lines of cleavage of the skin (Fig 10, 11) If the incisions are placed within these elastic lines, the tension of the surrounding tissue does not draw upon the edges of the skin Hence, the incised wound edges

fall naturally together thus placing the wound under minimal tension and stress

The simplest form of tissue-shifting is the closure of an elliptical defect by mobilization and approximation of the defect edges until a

a

b

Fig. 12, a. Closure of triangular defect of neck after excision of flat scar by starting with closure of corners. b Triangular defect changed into Y form.

linear suture can be made Triangular and square defects may be closed by starting with closure of the corners (a method already mentioned by Celsus) whereby the triangle is changed into a Y (Fig 12) and the square defect into a double Y (Fig 13)

If additional incisions are necessary to facilitate the mobilization of the tissue, one must be sure that the skin surrounding the defect is freely movable and that a secondary defect can be avoided or, if unavoidable, can be closed. So, for instance, in square defects, one or two flaps are formed (Fig 14, 16 third row) Both flaps are mobilized and shifted

a

b

Fig 13, *a* Large keloid scar of chest *b* Resulting defect after excision of scar was square, closed by starting with closure of corners, changing square defect into double Y

toward the midline, where they are fixed with sutures In triangular defects, the technic differs (Fig 15, *a*) One point of the triangle becomes the point of rotation The side of the triangle opposite this point is lengthened unilaterally or bilaterally, and the adjoining tissue is mobilized and shifted into the defect This method becomes more effective if vertical incisions are added to the first incisions, thus covering the triangular defect

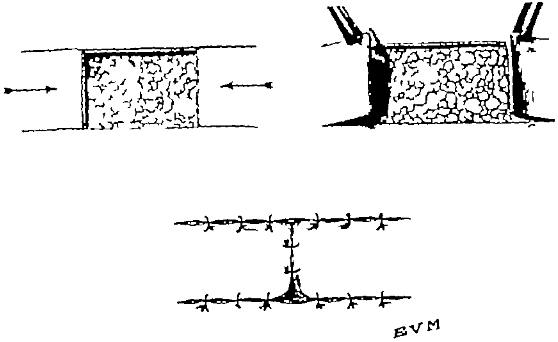


Fig. 14 Rectangular defect closed by shifting two flaps from immediate neighborhood into defect.

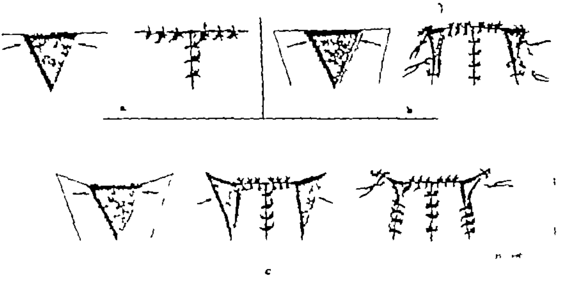


Fig. 15: Triangular defect closed *(a)* by lengthening one side of triangle unilaterally or bilaterally and rotating mobilized tissue into defect *(b)* by adding vertical incisions to first incision, thus closing defect with two square flaps. *c:* Facilitating closure of secondary defect by leading horizontal incisions obliquely upward, making outer angles of secondary defects less than a right angle.

with one or two square flaps (Dieffenbach, 1834) (Fig 15, *b*) However, in this method there is a secondary defect which one must be certain can be closed. Its closure may be facilitated by leading the incisions from the corners of the triangle, not horizontally, but obliquely upward (Fig 15, *c*), so that the outer angles of the secondary defect are less than a right angle and thus can be easily closed (von Szymanowski, 1858) (Case 23, p 877).

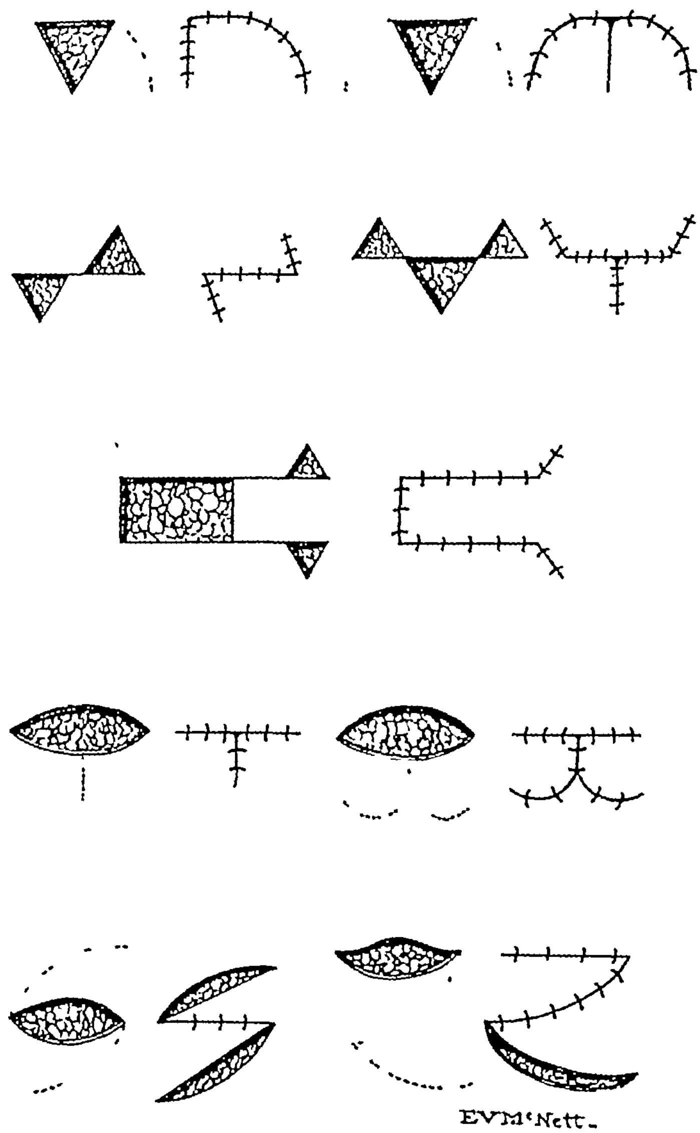


Fig 16 Methods of tissue-shifting

Another way of closing triangular defects is that of Burow. The principle of this method consists in sacrificing one or two triangles of tissue in the neighborhood of the tissue to be shifted, where there is surplus of skin, thus facilitating the tissue-sliding (Fig 16, second and third rows) (Cases 24, 25, pp 878, 880)

It is almost impossible to describe all methods which have been devised to facilitate tissue shifting Those which are still in vogue and which have been found helpful by the author are illustrated in Fig 16

Free Tissue-Grafting

The history of tissue-grafting is ages old its scientific basis however is of recent origin Ollier's work on transplantation of bone (1858) Reverdin's (1869) and Thiersch's (1874) on epidermis transplantation and Wolfe's (1875) and Krause's (1893) investigation in cutis transplantation lifted the veil of mysticism and placed this field of surgery upon scientific ground But in spite of numerous contributions, many essential questions remained unanswered

Regeneration of Tissue Investigation in tissue transplantation received an impetus after the discovery of the tremendous regenerative forces arising from the host tissue. The question What causes and stimulates regeneration? is to be answered The loss of tissue and the resulting wound The wound attracts hyperemia and unleashes the innate force of any tissue for restitution This is the start of growth and regeneration Depending upon location size and depth of the defect the healing process of the wound will result in a *restitutio ad integrum* or in a scar The latter is considered an inferior replacement of the defect Transplantation of tissue is performed to produce a more similar replacement of the lost tissue or to replace an already formed scar

The literature on the regeneration of free tissue grafts is voluminous Lexer's Neuhof's Peer's and R M May's monographs cover the world literature

A recent study by Peer and co-workers dealing with the behavior of autogenous human tissue grafts is stimulating Some of the conclusions regarding the general behavior of various kinds of grafts may be open to question but the fundamental findings leave little ground for argument Since the fate of some tissue grafts appears to depend upon the type of host with which the grafts are in contact the authors studied the behavior of human tissue grafts (1) when grafts were in contact with unlike tissue and (2) when they were in contact with like tissue They came to the conclusion that most of the tissue grafts (skin cartilage fat etc.) tend to survive whether they have been transplanted upon unlike tissue (skin upon fat or fascia, etc. cartilage within soft tissue etc.) or in contact with like tissue Bone muscle and nerve grafts however are an exception Bone grafts in contact with unlike tissue are replaced by the host fibrous tissue (except the septal bone graft which is a so-called membranous bone) in contact with living bone bone grafts regen

erate Muscle grafts always degenerate, whether the graft is in contact with unlike tissue or with muscle In nerve grafts, Schwann cells disappear when in contact with unlike tissue, when in contact with living nerve, however, nerve grafts survive The axons and myelin sheaths, however, degenerate, some become replaced later by ingrowth from the host nerve All grafts are kept alive initially by the exudation of plasma from the host tissue This plasma, however, acts rather to prevent desiccation, at least for all but the centrally located cells, than to provide nourishment and oxygen The authors obtained successful takes of autogenous skin grafts after wrapping them in a rubber sheet to prevent desiccation and keeping them in an incubator at body temperature for four days, those stored longer failed to take This simple experiment demonstrated that the cells in the skin graft will survive at body temperature without nourishment for four days when the cells are merely prevented from becoming desiccated

The vascular system in free grafts usually survives Hence, the ingrowing vessels form a direct anastomosis between the severed vessels of the graft Enderlen was able to see capillaries—injected with methylene blue—in a transplanted skin graft two days after transplantation Savenero-Rosselli found red blood corpuscles in the capillaries of the periphery of a transplanted skin graft twenty-four to thirty-six hours after the transplantation Experiments conducted by the author to study the vascularization of bone grafts demonstrate this vividly (Fig 31).

In the transplantation of tissue, the operator starts with the preparation of the host tissue, with the stimulation and liberation of the regenerative forces of the graft bed No regeneration will go out from a scar or from an infection Therefore, an infection—if any—has to be overcome first In case of scarring, all atrophic and cicatricial tissue must be removed until sound wound conditions are created Only under such conditions can the graft be kept alive and regenerated But this alone would not lead to a successful transplantation were it not for the functional stimulus or for the functional adaptation of the graft, which finally causes it to become an organic unit with the host tissue (Roux, Carrel, and Guthrie) So, for instance, the transplanted vein to fill a defect in an artery gradually hypertrophies A bone graft becomes either thinner or thicker according to the functional demand

Types of Transplantations: We distinguish autogenous, homogenous, and heterogenous transplantations, according to whether the transplant was taken from the same person, from another person, or from a different species. The greatest possibilities for survival and regeneration of a transplant are obtained by autogenous transplantation. The chances of

regeneration are much less in homogenous transplantation In heterogenous transplantations most transplants undergo rapid necrosis and absorption or encapsulation.

SKIN-GRAFTING

History Skin-grafting is a development of the nineteenth century Reverdin (1869) was the first one who placed skin-grafting upon a scientific basis He took small pieces of epidermis from a patient's right arm and transplanted them to a granulating surface on his left arm. The epidermal islands took and grew and gradually united. Reverdin's

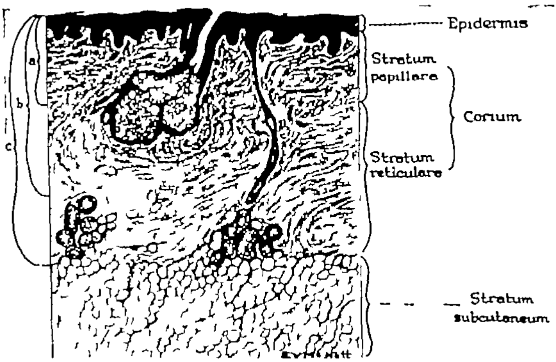


Fig. 17 Section of normal skin. *a* Thickness of thin split graft *b* of thick split graft *c* of full-thickness graft.

observations received great attention Lawson (1871) Ollier (1872), and Thiersch (1874) stimulated by Reverdin's findings experimented with larger epidermal grafts and are responsible for the introduction of this widely used method Wolfe (1875) went one step farther he used skin grafts consisting of the entire thickness of the skin But the credit for popularizing the use of large full thickness grafts goes undoubtedly to Krause, who in 1893 reported the successful use of more than 100 such grafts. In 1914 J S Davis introduced the small deep graft which was based on Reverdin's idea but instead of consisting of the superficial layer of skin it included the full thickness of the skin at its center tapering off toward the periphery

The real development of skin-grafting, however, started after the First World War, and resulted mainly from vast experience and improvement in technic Gillies, Lexer, Davis, Blair, Brown, and Padgett were foremost among others in developing new technics and increasing immensely the percentage of good results To J B Brown we are indebted for having the technic of skin-grafting perfected to such a degree that it has become the method of choice in many instances where a flap formerly was considered indicated

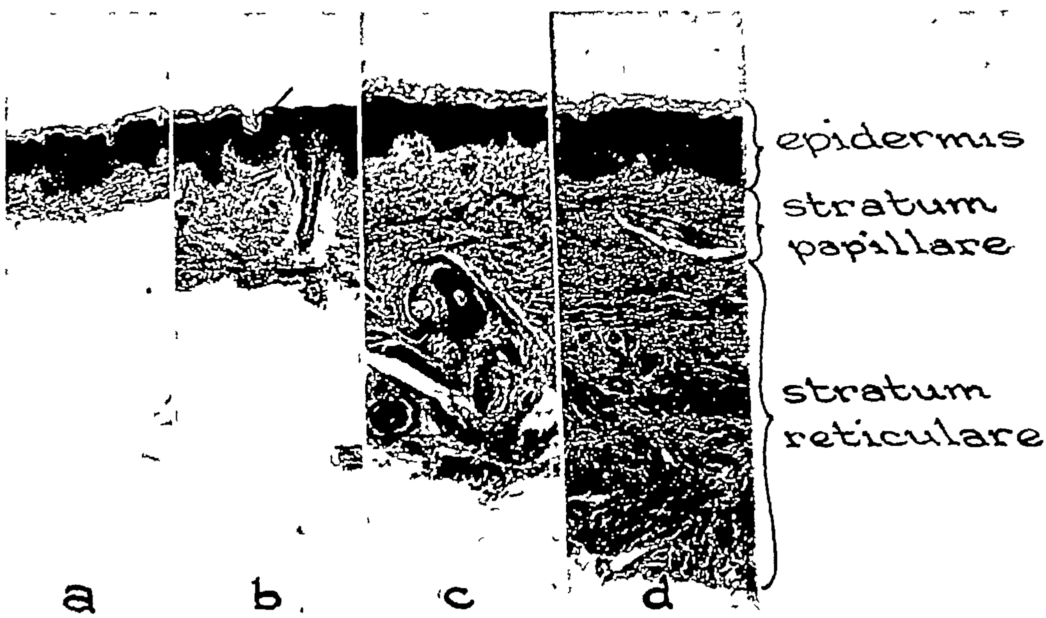


Fig 18 Photomicrograph showing various thicknesses of skin grafts *a* Original Thiersch graft. *b* Thin split graft (0 010 inch thickness) *c*. Thick split graft (0 022 inch thickness) *d*· Full-thickness graft

Choice of Graft The two most widely used grafts are the large split graft, consisting of partial thickness of the skin, and the large full-thickness graft The split graft, as originally used by Ollier and Thiersch, was cut thin, and consisted only of the epidermal layer of the skin with a small portion of dermis (Figs 17, 18), but these grafts are too thin for use on surfaces where firm coverage is required Hence, the graft should be cut thicker and should consist of from one half to three quarters of the thickness of the skin (Fig 18, *c*) The full-thickness graft consists of the full thickness of the skin without any subcutaneous tissue (Fig 18, *d*)

As to when a split graft is indicated and when a full-thickness graft, it must be said that the question occurs only when the host area is "clean" The full-thickness graft will not take on an infected area, no matter how harmless the infection. Therefore, on granulating surfaces only one type of skin graft comes into consideration, and that is the split

graft. But if the host area is clean then the question arises, Split or full-thickness graft?

In short it may be said On all surfaces where the cosmetic effect is not important and on surfaces that will resist subsequent contraction or on which allowance can be made for contraction split grafts should be used. The split graft is more easily obtained and applied takes more readily and the *after-care is less difficult* Furthermore the donor area heals more quickly and better because the epithelium regenerates from the hair follicles and sebaceous glands and covers the donor area completely But its drawback lies in the fact that it changes its color owing to pigmentation and does not resist subsequent contraction The recent work of Byars, Brown and associates in matching the color of skin grafts by tattooing appears to be very useful Brownish discolored grafts can be made lighter by superficial surgical abrasion (pp 149–150)

The full thickness graft changes its color also but not so much as the thinner graft. Furthermore the full thickness graft prevents recontraction to a certain degree Secondary contraction does not take place *so much in the graft itself as in the underlying host tissue* The thicker the graft the less is the amount of subsequent shrinkage. Hence, in regions in which the cosmetic effect is of importance or which are exposed to pressure and in which optimum relaxation is required the full thickness graft should be used

There may be exceptions to this generalization. To obtain a complete "take of the full-thickness graft, aside from the exercise of careful technic and asepsis, *the graft should be in intimate contact with the graft bed* The base upon which the full thickness graft is placed should be firm and even so that an adequate pressure dressing can be applied. Complete immobilization is also essential Therefore, in regions in which a firm, even pressure and immobilization cannot be accomplished the full thickness graft is not likely to be successful In those places (such as the cheek neck and axilla with their irregular contours) a thick split graft *is preferable this graft consisting of 70 to 90 per cent of the thickness* of the skin

Regeneration of Skin Grafts The regeneration of a free skin graft depends—like that of any other graft—upon the rapid establishment of its interrupted blood supply In the first twenty four hours, the vessels of the host tissue dilate plasma which preserves the viability of the graft, escapes and fills the spaces between graft and host and the plasma gradually changes into fibrin Hence the graft becomes anchored to the host tissue After about one to two days delicate vessels grow from the host tissue into the graft (Thiersch Carré Davis and Traut Enderlen

Savenero-Rosselli, Converse and Rappaport), after the third day, the graft itself takes active part in the regenerative process by marked proliferation of its epithelium. Between the fifth and tenth days after the operation, depending upon the size and thickness of the graft, organic union becomes complete after reestablishment of the interrupted circulation of the graft and development of a subcutaneous connective tissue, which anchors the graft firmly to the host. Besides proliferative changes, some degenerative changes in the epithelial and endothelial cells and the elastic fibers, with later regeneration, take place. Subsequent changes, such as change of color and contraction, may occur. Nerves begin to grow into the graft from the surrounding tissues about the third week, however, complete innervation may not occur for several months (Kredel and Evans, Davis and Kitlowski, L. Davis, McCarrol). A very fine description of the regenerative and histiogenic occurrences which lead to an organic unit of graft and host tissue has been published by F. Andina.

Condition of Patient: The patient's general condition has much bearing upon the outcome of a skin-graft operation. If the patient is in good health, the chances of "take" are much higher than in an anemic, chronically ill, dehydrated person.

Anemia and hypoproteinemia delay wound-healing (see Chapter III). Any disturbance of the fluid balance may affect normal metabolism. No patient should be skin-grafted unless the hemoglobin level is well above 60 per cent and the serum protein level above 6.5 gm. per 100 cc. Transfusions of blood and a high-protein diet are the chief remedies for correction of secondary anemia and hypoproteinemia. In some cases, severe burns, for instance, with large denuded areas, the hemoglobin and protein levels may remain low in spite of countermeasures. Under those circumstances, life or death may depend upon covering the raw surfaces, hence, one may be forced to proceed with skin-grafting, and even resort to homogenous grafts (p. 37) in spite of the risk. Fluid intake and output should be well balanced. A high caloric diet is important. Hermansdorfer's suggestion of an acid (salt-free) diet is a good one, but difficult to prepare individually. Vitamin deficiency must be watched for. Vitamin C is essential to wound-healing. Deficiency of it leaves the connective-tissue cells in a state of immaturity. Other vitamins, such as A, B, and D, are also essential to wound-healing. Hence, a high-vitamin, high-protein diet with an additional sufficient amount of ascorbic acid, administration of iron, and heliotherapy stimulates general and local health (see pp. 114, 136).

Preoperative Preparation of Donor Area: The donor area is shaved (with the exception of areas from which grafts are taken to be trans-

planted to a woman s face or to line cavities) preoperatively, it is washed with soap and water ether and alcohol, and covered with a sterile sheet. (Hexachlorophene compounds should not be used see p 4) No chemical antiseptic skin preparation should be used so as to avoid damage of the graft cells

Preoperative Preparation of Host Area The host area is prepared in a similar way unless the surface is granulating If the host area is granulating, the chances of take of a skin graft depend upon the type of graft used and the condition of the granulations Large skin (split) grafts will take only on pinkish, flat, healthy looking granulations. If the granulations are hypertrophic or chronically infected or sluggish the condition of the granulations should be improved by general and local measures before skin-grafting is attempted

Hypertrophic Granulations Hypertrophic granulations are exuberant, boggy edematous and overhang the wound edges To reduce their size and to change them into flat granulations several measures may be tried (1) Daily application of silver nitrate with a caustic stick or in 10 per cent solution followed by application of gauze soaked in Dakin s solution then a layer of cotton or mechanic s cotton waste and a firm pressure dressing which eliminates dead spaces and avoids venous and lymph stasis (see Chapter IV) An extremity should be immobilized and elevated (2) Another method consists of trimming the exuberant granulations with scissors followed by application of 10 per cent solution of silver nitrate and a pressure dressing (3) Daily baths and exposure to ultraviolet rays may be of value

Infected Granulations These granulations are gray and covered with fibrin and discharge a purulent exudate Under such conditions a daily saline bath is essential For patients with large infected areas, a daily tub bath, comfortably warm with 5 per cent salt may be lifesaving The surrounding skin should be cleansed with soap and water Daily débridement of dead tissue is necessary The area is covered with dressings soaked in Dakin s solution which is added at regular intervals In profuse discharge the dressings should be changed twice daily Cultures should be taken from the infected area and the proper antibiotic treatment administered (pp 116–118) If necrotizing processes are present sprinkling of the area with crystal sugar (which need not be sterile) may be given a trial. The sugar owing to its hygroscopic properties causes a profuse exudation and hence an elimination of fibrinous membranes and necrotic tissue If the granulations have a tendency to bleed application of zinc peroxide is recommended (Altemeier and Carter) If the discharge becomes less the wet dressings are alternated with ointment, such as cod

liver oil, scarlet red, or mercury ointments, or with balsam of Peru Heliotherapy may be of value But twenty-four hours before the operation, isotonic saline dressings are applied, which are moistened at regular intervals

The Pseudomonas aeruginosa (Bacillus pyocyaneus), harmless to wound-healing, is a definite handicap in skin-grafting Grafts do not take well or do not take at all in its presence The difficulties in eradicating it from the tissues are well recognized If there is a mixed infection, chemotherapy should be undertaken The author has found that in combating the other germs and checking their growth, a marked reduction of the pseudomonas infection could be noticed Local therapy consists in application of 3 per cent acetic acid solution The dressings should be kept moist constantly and changed daily In stubborn cases, 3 per cent acetic acid solution and Dakin's solution are applied alternately at three-hour intervals for forty-eight hours

Sluggish Granulations In sluggish granulations, the response to the wound stimuli is lacking, hence the healing process has to be induced This may be done by touching the granulations with a caustic stick and applying various stimulating substances, such as Dakin's solution, mercury ointment, and cod-liver oil ointment If the circulation is at fault, as in old leg ulcers, it should be improved if possible If an old ulcerative area is surrounded by dense cicatricial tissue, the entire surface, including the granulating area, ought to be excised down to the firm fibrous-tissue base, and this base should be covered immediately with a skin graft.

Time for Grafting Granulations When are granulations ready to be skin-grafted? To determine this, the macroscopic appearance of the granulations is of more importance than a bacterial count Granulations are ready if they are bright red, small, or at least not too exuberant, and free from purulent discharge All antiseptic solutions are replaced the day before the operation by isotonic saline dressings, which are moistened at regular intervals

Split Skin Grafts

Preparation of Recipient Area· The operation starts with the preparation of the recipient, or host, area, which is changed into a clean wound In case of a granulating area, the granulations are not touched if they are flat But if the granulations are hypertrophic, they are sliced down—not scraped—with a sharp, long knife (transplantation knife) to a yellow, well-vascularized layer, which constitutes the base of the granulations The next step is thorough hemostasis Spurting vessels

should be ligated The oozing is controlled by pressing hot wet compresses upon the wound The heat accelerates coagulation of the blood. If this procedure does not control the oozing one may try the following The wound is left open so that the blood has a chance to clot while a piece of wet gauze pressed against one edge of the wound absorbs the blood When the blood commences to become serous the wet blood soaked gauze is pressed firmly upon the wound to promote adherence of the clots Application of a solution of 1 1000 epinephrine may be the last resort.

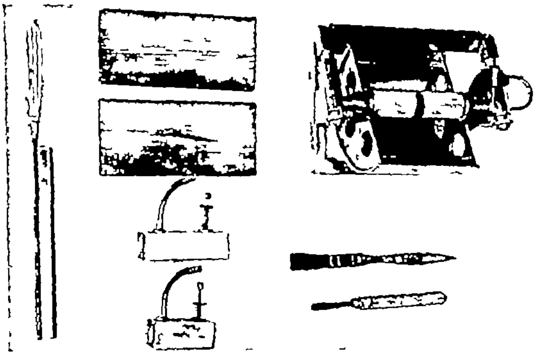


Fig. 19 Skin-graft table. Blair Brown skin-graft knife *(left)* Two wooden boards *(center top)* Two Blair Brown suction cups *(center bottom)* for stretching donor-area skin (see text) Padgett Hood dermatome *(right)* on stand.

Removal of Graft The ordinary donor areas are the thighs or upper arms preferably the hairless inner parts of these extremities or the back abdomen or chest may also be used The skin of the donor area is moistened with isotonic saline solution and then stretched between two boards to obtain an even flat surface. A common mistake is to press the boards into the flesh rather than to pull and stretch the skin flat the result is an uneven surface The right board is held by an assistant, the left by the operator The former board is held firmly in place the latter is pulled immediately in advance of the knife The graft is now cut with a long broad bladed sharp knife Blair Brown s skin-graft knife is a very good one (Fig 19) Marcks added an attachment to the Blair Brown

skin-graft knife which allows calibration of the skin graft, and thus assures equal thickness of the graft. The knife is placed flat on the skin, and with a rapid forward and backward motion the knife penetrates the skin and splits it (Fig 20) (For examples of skin-grafting, see Cases 93, 94, pp 972, 974)

Use of Suction Cups The boards may be replaced by suction cups (Blair-Brown) (Fig 19) These are hollow brass boxes with the under

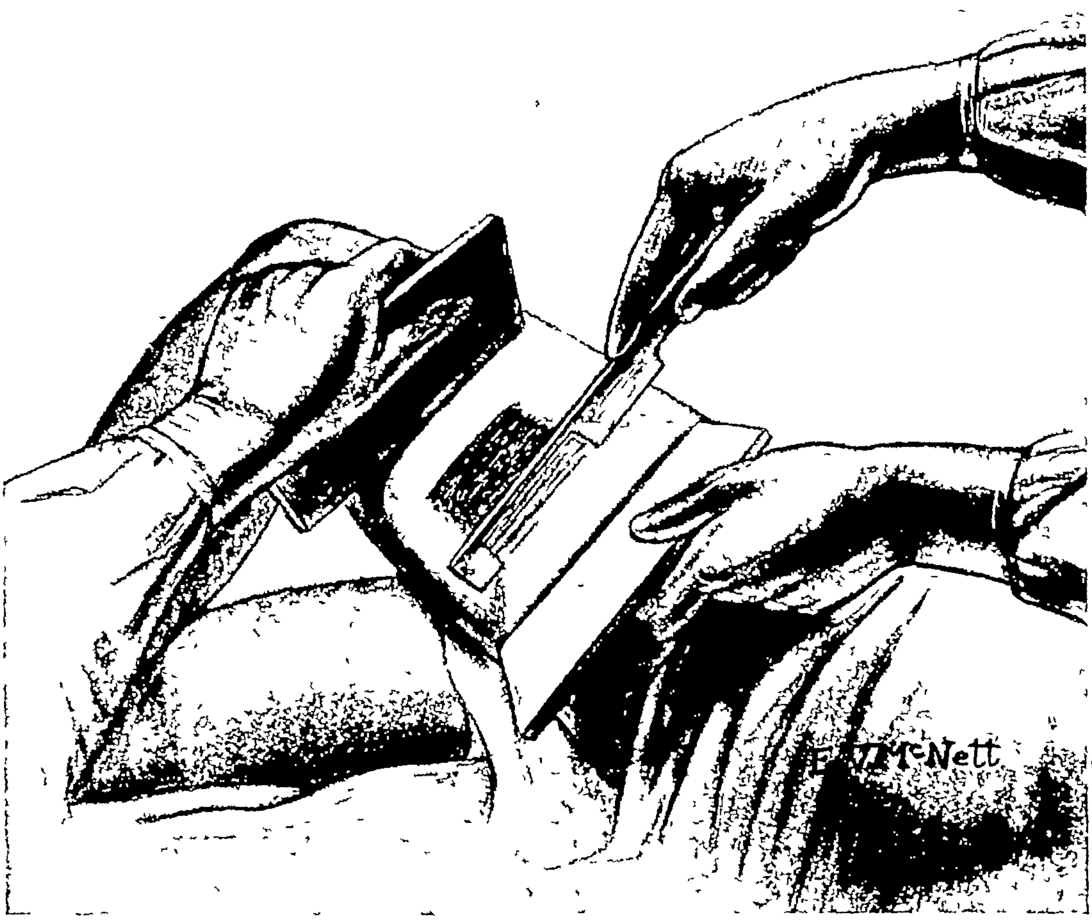


Fig 20 Technic of cutting split graft with skin-graft knife Skin is stretched between two boards One board is held by assistant Second board is pulled by operator immediately in advance of knife

side open for suction on the skin Within the opening, there is a series of transverse bars, which prevent the skin from being drawn bodily up into the box The ends are corrugated for gripping, and are 2 5 cm (1 inch) square A tube leads from the top of the box, and is attached to a noncollapsible rubber tube connected to a strong suction machine There is a valve on top of the box for adjustment of the suction The suction usually is one half an atmosphere of negative pressure These boxes come in three different lengths Before the suction cups are placed

on the donor area the skin is greased with a thin film of petrolatum The boxes are now placed on the skin neither pressing nor raising the skin the box in the operator s hand is drawn immediately in advance of the knife This technic as developed and used by Blair and Brown provides an improved means for obtaining grafts of uniform thickness An

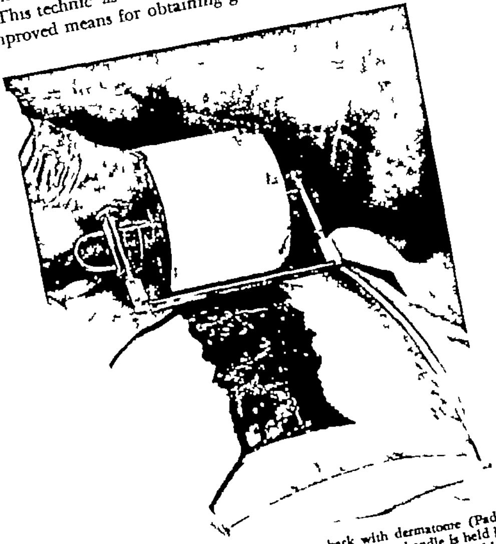


Fig 21 Technic of cutting skin graft from back with dermatome (Padgett Hood) Drum and donor area are painted with rubber cement. Drum handle is held in left hand, handle of knife-holder in right hand. Drum is placed on area to be cut and knife worked from side to side while drum is turned so as to lift skin slightly

other improvement is Barker s Vacu Tome a combination of a suction cup and a movable skin graft knife which can be adjusted to any thickness of the graft

Use of Padgett Hood Dermatome The best assurance for obtaining a skin graft of uniform thickness is offered by the Padgett Hood skin-graft mechanism called the dermatome (Fig 19) The dermatome consists principally of a drum with a movable knife adjustable to any given distance from the drum A fine film of rubber cement is painted on the

drum and on the skin of the donor area After the cement is allowed to dry slightly, the drum handle is taken in the left hand and the handle of the knife-holder in the right hand. Now the drum is placed on the surface to be cut, and is permitted to remain for a few seconds to allow it to adhere The knife is worked from side to side by making quick, rather short strokes of the knife-holder. The drum is turned in such a fashion that it lifts the skin slightly, but not too much (Fig 21) With this

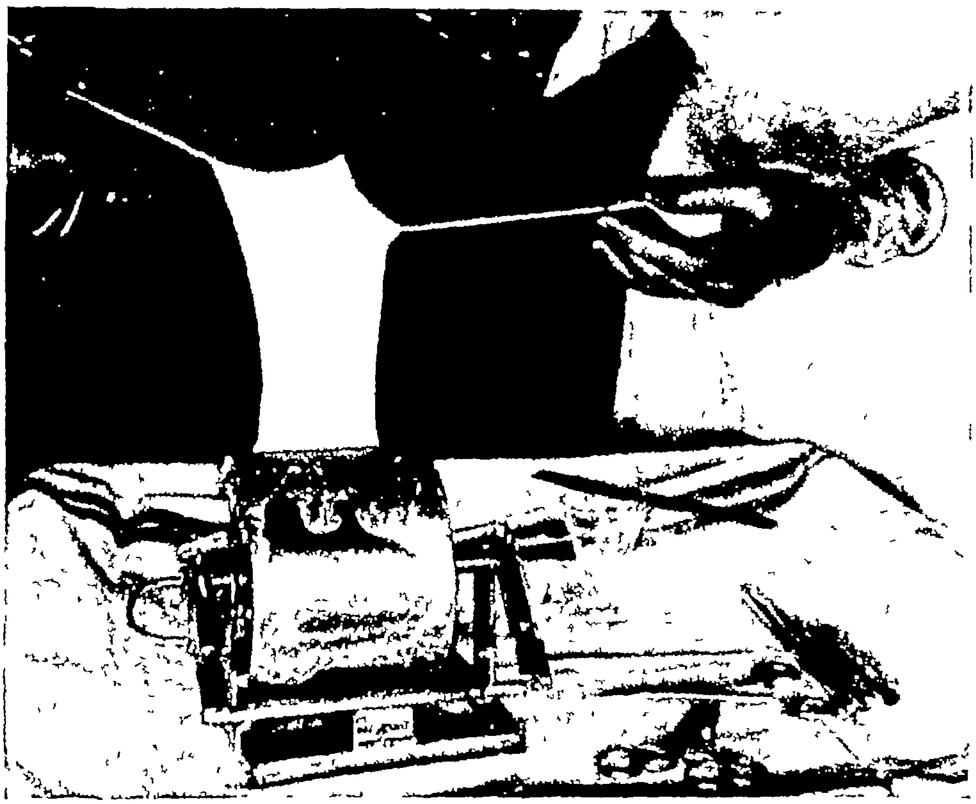


Fig 22 Skin graft is removed from drum by grasping it with hemostats at extreme points and pulling it from drum

mechanism, it is possible to remove a sheet of skin as large as the drum, or 10 by 20 cm ($3^{15}/_{16}$ by $7\frac{7}{8}$ inches), or smaller, and to cut it absolutely uniform in thickness, furthermore, the thickness can be varied by turning a calibrating mechanism which varies the distance of the knife from the drum.

INDICATIONS FOR VARYING THICKNESS Padgett indicates the varying thickness as follows In an adult when the main indication is one of resurfacing a granulating area, usually the graft is cut from 0 010 of an inch to 0 014 of an inch thick. When a clean raw surface is to be covered and the indication is one in which appearance is a prime factor or it is essential to have minimal contracture, the grafts are cut from 0 022 of

an inch to 0 028 of an inch It is found that at this thickness sufficient subepithelial elements remain in the base for early regeneration When appearance or minimum contracture is not such a clear-cut indication and the certainty of take seems to rank relatively high in the balancing of the essential factors the grafts are usually cut between 0 016 and 0 020 of an inch thick In young children the graft should not be cut thicker than from 0 010 to 0 012 of an inch In young children how ever the author has found 0 008 of an inch a satisfactory thickness for covering granulating areas.

REMOVAL OF GRAFT FROM DRUM The graft is removed by grasping it with hemostats at extreme points and pulling it from the drum (Fig 22) It should be kept from folding since the rubber cement may glue the adherent surfaces together If this happens the epithelial side of the grafts is rubbed gently with a piece of gauze soaked in the patient s blood

BACKING FOR GRAFT To prevent the graft from folding and from shrinking the use of backing material has been advised Webster uses pliofilm Green Levenson and Lund use nylon backing for dermatome grafts The author has found the nylon cloth very satisfactory The drum of the dermatome is coated with cement A fine-gauge nylon cloth is cut the size of the drum and cemented to the drum as smoothly as possible A new coat of cement is now applied to the nylon and to the donor site and the graft is cut as already described The graft with its backing is removed from the drum with hemostats and placed on the host area Since the backing prevents the graft from shrinking it may not be neces-sary to hold the graft in place with sutures In many cases however the graft must be sutured accurately to the wound edges and this can easily be performed through the nylon backing and the graft The nylon backing should be removed at the time of the change of the first dressing and can easily be peeled off The nylon cloth can be sterilized as easily as any other textile Backing of a skin graft, as advantageous as it is, should be avoided however when the host area is irregular (chin neck line axilla for example) since the backing material does not yield as readily as the skin

Reese Dermatome This is constructed on the same principle as the Padgett dermatome In addition it provides a mechanism by which the backing material (dermatape) can be applied It is very accurate but if the operator while cutting the graft finds its thickness not proper he must remove the dermatome from the donor area for adjustment

Electrodermatome Introduced by Brown this ingenious mechanism is motor-driven and uses an oscillating knife The knife can be set with

a calibrating scale to obtain any graft thickness, and cuts rapidly It is not necessary to use adhesives to lift the skin The length of the graft is limited only by the donor area. The availability of donor areas is limited, however, such areas as the abdomen, for example, cannot well be used because of their softness Furthermore, backing of the graft is not possible A recent innovation is the Padgett-Hood electrodermatome This is latched directly to the motor, which serves as the handle

Schuchardt Dermatome This is a very useful device, and requires no adhesive, suction, or electricity Owing to its weight, it adheres to the skin The graft is cut by side-to-side strokes of a knife blade, which, by means of a knife handle, is attached to the dermatome The blade can be set by thumbscrews to any distance from the frame

Transfer of Graft: The skin graft, after it is cut, is transferred to the wound and spread over it It is not good practice to overlap the graft with the edges of the defect; most of the overlapping tissue would become necrotic and slough Parts of the overlap, however, would regenerate, thus causing an irregular hypertrophic scar The graft should be trimmed so that it fits perfectly into the defect. The graft is fastened to the wound edges with continuous or interrupted silk sutures, and also, if necessary, to the base of the graft bed with basting stitches A few stab holes may be cut in the graft with a pointed knife to allow exudate and air to escape (Case 97, p 978) In grafts transplanted to the face and neck, these holes should be omitted On granulating areas where there has been no evidence of infection, antibiotics should be administered pre- and postoperatively

Dressing of Grafted Area: Obviously, much of the success of skin-grafting depends upon the proper dressing. The graft must be kept in close contact with the graft bed This is done by exercising proper pressure Too much pressure, however, is apt to damage the graft. Furthermore, the grafted area should be immobilized if possible Before the pressure dressing is applied, a roll of gauze soaked in isotonic saline solution is rolled over the graft to press out air bubbles and blood, the graft is covered smoothly with one or two layers of bismuth tribromophenate (xeroform) gauze (bismuth tribromophenate, 3 0; paraffin, 1 0; white wax, 1 0, petrolatum, 95 0) or scarlet-red gauze. In large areas, rolls of gauze, wrapped around the extremity, for instance, are more convenient than single layers An ordinary 3- or 4-inch bandage, in which the ointment is incorporated, fulfills this purpose well Then follow several layers of gauze soaked in isotonic saline solution They should be cut so that the first layer covers only the graft, the second and third ones each somewhat larger Then follows the medium which will transmit an even

pressure This may be a thick layer of sterile cotton or mechanic s white cotton waste (J B Brown) For a small area one may also use a sterile marine sponge or rubber sponge The entire dressing is now placed under firm pressure with gauze bandages followed by elastic bandages If one is dealing with an extremity it is then immobilized and elevated

Plasma-Coagulum Fixation A physiologic adhesive medium for the attachment of skin grafts has been devised by Sano The author has used her method occasionally with gratifying results The method consists of preparing two solutions which when brought together develop a fibrinous adhesive coagulum simulating, in intensified forms the normal adhesive process occurring in wounds

Its chief disadvantage is that since no dressing is applied the grafted area must be carefully protected from mechanical interference This in certain regions of the body is almost impossible to accomplish The time consumed in preparing the solution is another disadvantage

Fibrin Fixation To obviate such delay a fibrin fixation method has been worked out (Tidrick and Warner Young and Favata Cronkite Deaver and Rosner) which in this author s experience does not provide as firm adhesive qualities as Sano s method The raw side of the graft is saturated with human plasma (plasma from the plasma bank can be used) The recipient area is flooded with a thrombin solution * The fibrinogen of the plasma flooded graft if brought in contact with the thrombin on the recipient area clots almost instantly The grafts should not be moved after once applied to prevent breaking up of the clots. A light moist dressing is applied to protect the graft In case of an extremity immobilization should be undertaken as an additional measure

The author occasionally (when there is much oozing from the wound) uses a modified technic of the fibrin fixation method by injecting thrombol† (a local thromboplastin) This is a suspension of all blood clotting principles extracted from fresh brain tissue of the calf To prevent moving of the graft after application of the thrombol the following procedure is employed The graft is sutured in place and just before application of the pressure dressing a sufficient amount of thrombol is injected between graft and host area and the pressure dressing is applied immediately Thus the method is used not so much for dispensing with suturing as for promoting quicker adhesion of the graft and controlling oozing

Care of Donor Area The donor area is dressed with bismuth tribromophenate (xeroform) gauze or other ointment and covered with

* Thrombin topical (Parke Davis and Company)
† Sharp and Dohme.

dressing pads. The author highly recommends rayon also, which has been introduced by Neal Owens It has a sufficiently close weave to block ingrowth of capillaries into the fabric, permits adequate drainage, has a low coefficient of friction, and permits easy sterilization It works even better if it is coated with a thin layer of a bland ointment There are numerous similar products now available Artz recommends the exposure treatment (pp 133–134)

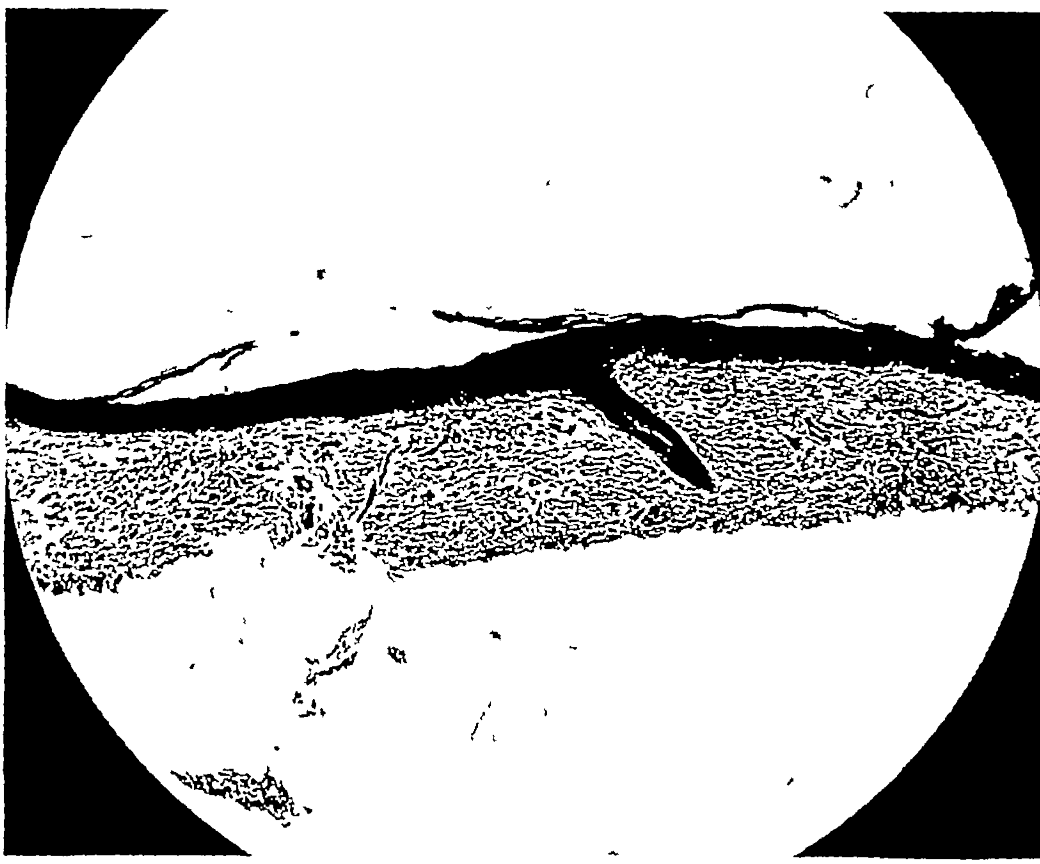


Fig 23 Photomicrograph of split graft taken from a donor area used twice before

After-Treatment: On clean wounds, the dressing may remain in place for from eight to ten days, unless there is evidence of infection On granulating wounds, it should not remain longer than from five to seven days It is then changed, the sutures are removed Any slough is trimmed away immediately with scissors The dressings from now on consist of moist (saline) gauze until the graft has healed (two or three weeks). It is then protected with ointment dressings, and may be massaged daily with cocoa butter or cold cream

The dressing of the donor area is allowed to remain in place until it comes off by itself, i e , after the donor area has been reepithelized If the graft has been cut thin, the donor area may heal in one week

and—if necessary—be ready in two weeks for furnishing another graft (Fig 23) If the graft has been cut thick several weeks may elapse before reepithelization occurs (See Cases 93 94 pp 972 974)

SPLIT INLAY AND OUTLAY GRAFTS

This method is used mainly for the resurfacing of those regions which are difficult to reach or in which no pressure dressing can be applied as in cavities such as the mouth orbit, and vagina This method which was introduced by Esser in 1917 consists of transplantation of split grafts wrapped around a mold of dental compound Esser used this method for relining the obliterated labiogingival sulcus. From an incision below the chin the graft with stent was buried without opening the oral cavity the incision was closed after ten days the mold was removed through an incision in the mouth Esser called this method epithelial inlay-grafting Later on this principle was modified (Waldron Gillies and Pickerill) by applying the graft-covered stent directly to the surface to be lined and was called epithelial outlay-grafting

Technic (Case 76, p 945) The surface to be grafted such as an obliterated labiogingival sulcus is changed into a fresh wound. A piece of dental compound softened in hot water is pressed into the cavity then carefully removed and placed in cold water A split graft is removed from a hairless region (not to be shaved!) and wrapped around the mold with its raw surface outward The graft edges are sutured together over the mold Another way of holding the graft on the mold is by means of collodion applied to the stent before wrapping the graft around it Stent and graft are now inserted and either kept in place by suturing the wound edges over it together and thus burying the stent (inlay-grafting) or a suture is passed through one wound edge and the corresponding edge of the graft. The same suture running across the mold engages the opposite graft edge and its corresponding wound edge and is then tied Several such sutures may be necessary (Figs 199 225 236C 296 Cases 69 88 pp 937 962)

After Treatment Postoperative care consists of keeping the surrounding area clean with mild antiseptic solutions The sutures are removed after one week and the mold is lifted out. The grafted area is cleansed by irrigation and gentle swabbing with boric acid solution and the mold is reinserted for several days or weeks until the graft has firmly healed in place

HOMOGENOUS SPLIT GRAFTS

Homogenous grafts (grafts taken from another person) will take satisfactorily but are absorbed in a few weeks unless used in identical twins

(Bauer, Brown, and others). There is apparently no relation between the "take" of a homogenous graft and the blood groups (Loeffler) A conflicting mass of literature about this fascinating subject has accumulated during the past two decades, and many hypotheses have been advanced to explain the initial take of the graft and its ultimate absorption. None has been proved and none has had practical value Scepticism has prevailed even among the foremost research groups The literature has been thoroughly covered up to 1950 by Rogers and has accumulated since Reference is made to Andina's stimulating work Rogers receives an overall impression that many of the past research attempts were made without any well-thought-out plan or procedure, and that the "inevitable failures" caused a certain degree of fatalism He justly states that "the field of homograft research needs more optimists" To stimulate further research, he presents a useful guide and table of observation And since many research groups have given up further work or have been unable to prove their hypotheses, this field is wide open for further constructive thought The use of the tissue-culture method, as used first by Converse and his associates for determining the viability of the cells in "bank tissue," or the use of the transparent chamber, as used by Conway et al, is likely to stimulate further research in this direction

The only practical side in homo-skin-grafting is the initial "take" of the graft Its application obviously requires donors, this may in certain cases hamper the practicability Dogo utilized stored cadaver skin grafts successfully in a few cases, and this may well prove practical, as demonstrated by the establishment of a skin bank for post mortem homografts by Brown and his associates

Homogenous grafts should be applied only when it is thought that the patient cannot stand a long operative procedure and when there is no sign of subcutaneous epithelization It may be a life-saving procedure to apply large sheets of split homogenous grafts when a patient cannot stand a long operative procedure and is steadily slipping owing to debilitation and pain Homogenous grafts take almost as well as autogenous grafts, they become vascularized (Converse and Rappaport, etc), and survive for from three to six weeks During this period, the patient is given a respite from pain and dressings His general condition picks up, and there is a stimulus to his own epithelization so that complete healing may even occur after absorption of the graft (Case 93, p 972)

Full-Thickness Grafts

Technic: In transplanting grafts consisting of the full thickness of the skin, asepsis, thorough hemostasis, and very gentle handling of the graft

are of utmost importance The host area is changed into a clean wound. Then follows thorough hemostasis, in much the same way as already described (p 28) The next step is to cut a pattern of the host area Tinfoil rubberdam, or chamois may be used for this purpose The simplest procedure is to press a piece of linen upon the wound Upon its

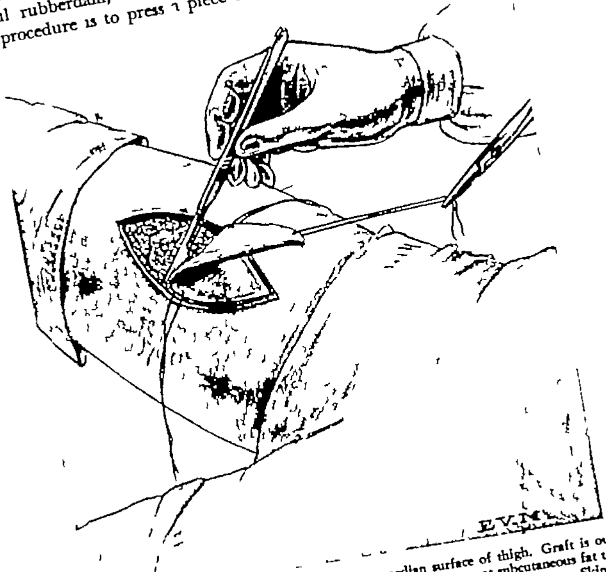


Fig. 24 Removal of full-thickness graft from median surface of thigh. Graft is outlined with incision which penetrates whole thickness of skin, but not subcutaneous fat tissue. Silk sutures, passed through extreme corners of graft, are used for traction. Skin is separated from subcutaneous fat tissue. No fat tissue should remain on graft.

removal one will find the bloodstained outline of the wound on the material This is cut out with scissors and is transferred to the donor area

The bloodstained side of the pattern is laid upon the skin of the donor area With a small sharp knife the outline of the pattern is circumscribed on the skin of the donor area The incision after removal of the pattern is deepened and includes the whole thickness of the skin

A fine silk suture is passed through each corner of one side of the graft Under steady traction on these sutures, the skin is separated from the subcutaneous fat tissue No fat tissue is allowed to remain on the graft (Fig 24) Another method of cutting the graft is to remove it with some fat tissue attached The fat tissue is trimmed away with scissors after the graft is removed The graft is now laid upon the wound in correct

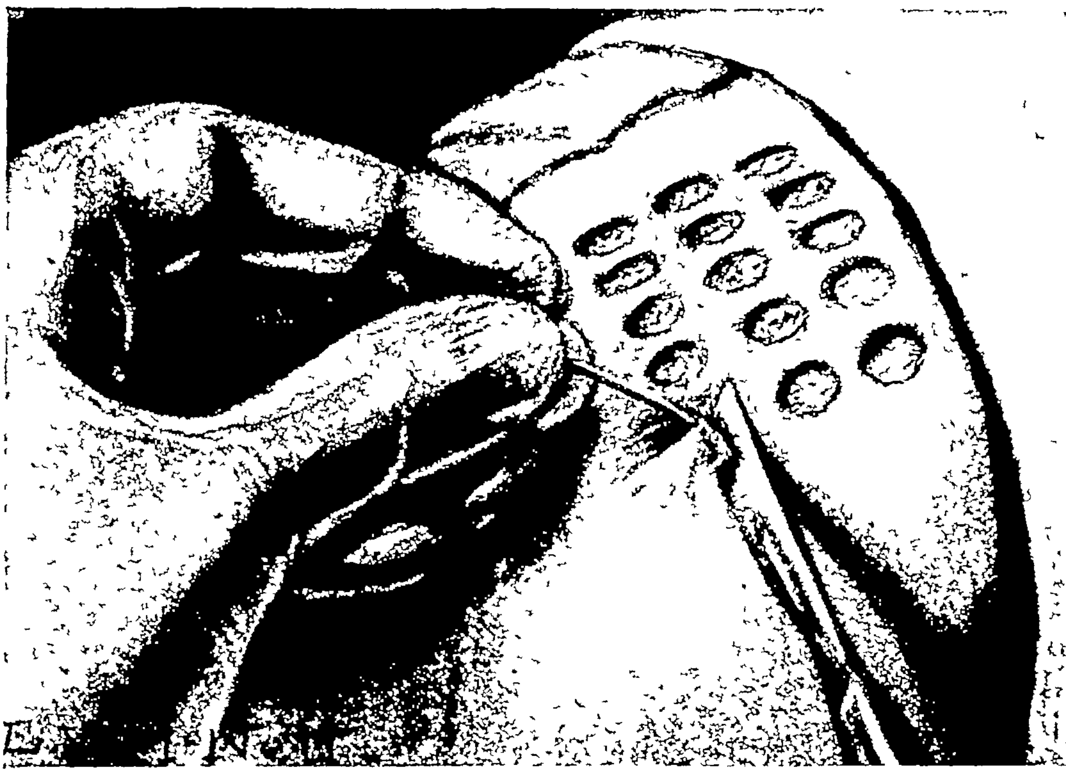


Fig 25 Removal of small deep grafts Straight needle held in artery clamp engages bit of epidermis which is raised to form a small cone Base of cone is cut through while depressing blade of knife

position The traction sutures are used to anchor the graft to the host area With fine silk sutures, the remainder of the graft is fastened to the wound edges

Dressing of Grafted and Donor Areas: A firm pressure dressing, similar to that used in split grafts, is applied, and, if possible, the grafted area is immobilized by proper splinting The donor area is closed by sliding the wound edges together after undermining the adjacent skin, or, in case of a large defect, the defect is covered with a split graft, which is kept under proper pressure.

After-Treatment: If there is no evidence of infection, the pressure dressing is allowed to remain in place for from eight to ten days It is then changed, and the sutures are removed In some cases, blisters may

develop on some parts of the graft they should be opened and trimmed if infected but left closed if they contain clear fluid The graft is covered with moist (saline) gauze and another pressure dressing is applied for a period of about three to five days. After the graft has healed, it should be protected from mechanical injury for at least three or four weeks with ointments and dressings and massaged daily with cocoa butter or cold cream

Small Deep Skin Grafts

These grafts were devised by Davis (J S) in 1914 They are small cones of skin consisting of the full thickness of the skin in the center gradually tapering off toward the periphery They take on many areas (chronic ulcers for example) where other types of grafts fail Their simplicity of application and ready take are advantages but the hobnail appearance of the host area the pitted appearance of the donor areas the longer healing time and the tendency to contraction are drawbacks that make them practical only if necessity demands. These grafts may be used on granulations or on clean wounds The preparation of these surfaces is the same as described previously (p 28)

Technic: A straight needle held in an artery clamp is engaged in a bit of epidermis which is raised to form a little cone The base of this cone is cut through after the blade of the knife is depressed (Fig 25) The graft should be from 0 2 to 0.5 cm ($\frac{3}{32}$ to $\frac{7}{32}$ inch) in diameter The graft engaged by the needle is transferred to the host area The grafts should be placed in rows close to each other

Dressing: The grafted area is covered with a piece of wide meshed paraffin gauze over which a single thickness of bismuth tribromophenate (xeroform) gauze is placed followed by a pressure dressing The grafted part should be immobilized The donor area is dressed with bismuth tribromophenate gauze

After Treatment If the grafts have been placed on a granulating wound the original dressing should be changed after four days. If placed on a fresh wound the dressing is changed after one week The after treatment consists in the application of some bland ointment when dealing with granulations and the granulations become exuberant, Dakin s solution may be used after one week The grafted area should be protected from injury for several weeks.

Sieve Grafts

This rarely used type of graft devised by Douglas in 1930 is a full thickness graft with multiple perforations. These perforations are cut

with a punchlike instrument before the graft is removed Thus, skin islands are left on the donor area after removal of the graft These islands will fuse, thus causing epithelization of the donor area Douglas claims that the perforations in the graft provide adequate drainage and make it resistant to infection, thus insuring a very high percentage of "take"

Tunnel Grafts

Tunnel grafts were devised by Keller in 1930 His method, which has only limited use, consists in burying a full-thickness graft into a tunnel which, in a granulationing area, for instance, is made by passing a scalpel between the granulations and their vascular membrane. The raw surface of the graft comes to lie upon the membrane; a pressure dressing is then applied, and is changed after five days The roof of the tunnel is removed on the fifteenth day In cases of cicatricial contracture, a tubulated full-thickness graft (inside out) is inserted into the tunnel with its seam beneath the roof, the tunnel is divided after the fifteenth day along the seam (line of suture) of the tubulated graft

Dermal Grafts

This type of graft consists of the full thickness of the skin minus its epidermal layer (hence the term "dermal" graft, the term "cutis" graft should be avoided since under "cutis" all layers of the skin are understood) The graft is implanted into the body tissues to fill certain defects such as incisional hernias, dural defects, and tendon defects, or to build up depressions in such regions as the face and head (Case 16, p. 868) It is proved that it heals better and more quickly than other grafts (such as fascia and fat) used for similar purposes, and according to Rhen, it adapts itself readily to the functional requirements through functional metaplasia (Swenson) Loewe (1913) was the first to use this type of graft Rehn (1914), however, deserves the credit for popularizing it The literature upon this subject has been recently reviewed by Cannaday. The objection that cysts form from the buried glandular structures is apparently not holding true Peer and Paddock examined dermal grafts from seven days to one year after implantation, and found disappearance of sebaceous glands and hair follicles and degenerative changes in the sweat glands.

Mair takes the entire thickness of the skin (cutis) to bury as a graft—a method used mainly in repair of hernias From his rather large series of cases and those of others (Zaveta et al , Marsden), it becomes evident that, in spite of the buried epithelial layer, inclusion cysts do not form If large buried grafts must be used, the full-thickness skin graft is of no

advantage since the donor area would need another split graft for closure.

Technic. The graft is obtained in one of two ways (1) A thin layer of epidermis is sliced off and then the required size of the dermal graft, cut like a full thickness graft The resulting defect of the donor area is covered with the removed epidermis (Fig 271) (2) The skin is removed with the dermatome (drum type dermatome) as a full thickness graft. The skin remains on the drum while the knife handle is reset The graft is now split so that only a thin layer of dermis is left behind on the drum which can be utilized to cover the donor area

Concerning transfer fixation and postoperative treatment of dermal grafts the reader is referred to pp 467–468 and Cases 90, 112, pp 966 1003

Implantation or Seed Grafting

This method introduced by Braun consists of implanting tiny pieces of epidermis (3 mm square [1/8 inch square]) into a granulating surface The grafts inside out are pushed into the granulations with the blunt part of a needle The various seeds are 1 cm (7/10 inch) apart from each other After about seven days the epithelium regenerating from the graft, reaches the surface and commences to spread hence epithelial islands are formed which finally fuse This method of skin grafting may be useful after every other available method has consistently failed.

MUCOUS-MEMBRANE GRAFTS

Free transplantation of mucous membrane is not so widely used as that of the skin owing to lack of material Large mucous membrane defects are preferably replaced by skin than by mucous-membrane grafts The latter's chief use lies in replacing conjunctival lining of eyelids and eye sockets The chief sources are the lips and cheeks. The lower lip is turned outward and downward and held in this position with hooks or traction sutures The graft is sliced off with a razor knife in the same fashion as a split graft is cut (p 20) If the graft is taken from the cheeks it is cut like a full thickness graft (p 24) For transfer and aftertreatment see p 34

FAT-TISSUE GRAFTS

Transplantation of fat tissue first attempted by Neuber (1893) attracted attention when Czerny (1895) reported his celebrated case of an actress in whom cystic tissue of the left breast was removed and replaced by a lipoma from the patient's lumbar region The breast remained well formed and the lipoma did not grow The real impetus

to this work, however, was given by Lexer and his associates From experimental and clinical observations he states that about one third of the fat transplant survives, the other two thirds undergoes degeneration in the form of cyst formations These cysts are due to fat necrosis The degenerating fat cells coalesce and form cysts The cysts are invaded by

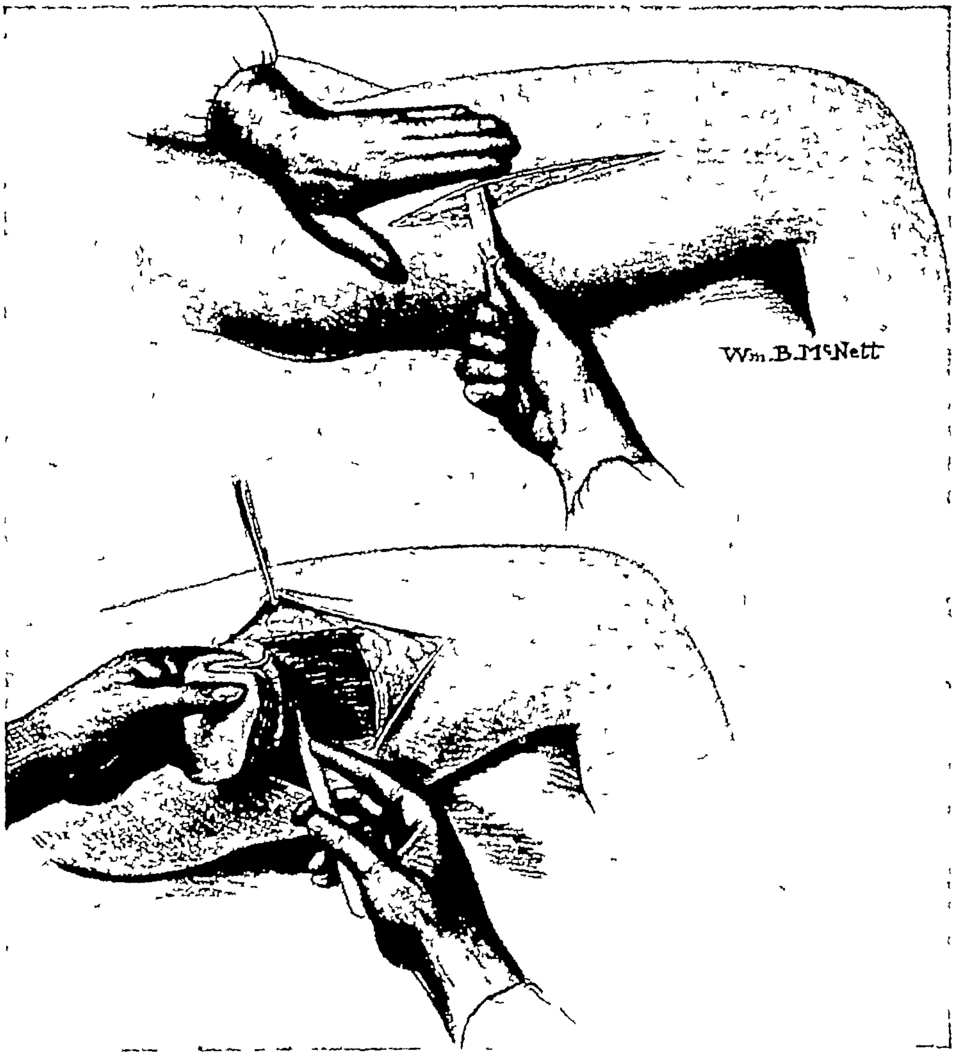


Fig 26 Removal of fat-tissue graft from lateroposterior surface of thigh Skin is severed from subcutaneous fat tissue with amputation knife Fat-tissue graft is removed with underlying fascia lata

round cells, which absorb the fat globules. Some of the round cells may change into embryonal fat cells, and there may be an actual regeneration of fat The surviving fat tissue may become atrophic, but does not change character, as the author can confirm Fat-tissue grafts are used to fill surface depressions, to smooth contours, to obliterate dead spaces, and to prevent adhesions. The graft should be taken two thirds larger than required to counteract degeneration and shrinkage Peer advises to have

a patient on a fat free diet before the operation Furthermore it is advisable to remove some of the underlying fascia in connection with the fat (Fig 26) The fascia limits the shrinkage of the graft Derma (p 42) left in contact with the fat graft seems to limit shrinkage even more The graft may be taken from the abdomen from the latero posterior surface of the thigh or from the gluteal folds If a fat graft plus derma is taken the epidermis is removed with the dermatome The derma and fat tissue is then cut en bloc and transplanted The dermal part of the composite graft should be placed upon an even part of the wound cavity It may also be practical to cut a composite full thickness skin and fat graft en bloc and remove the epidermis subsequently (p 485)

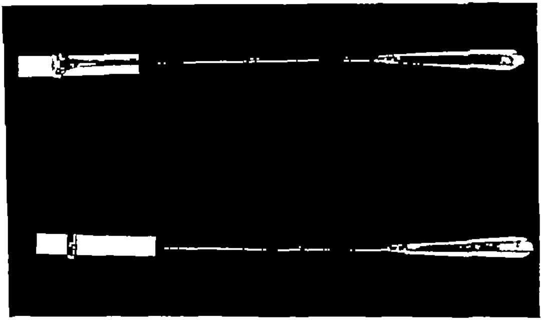


Fig. 27 Fascia-stripper consisting of long handle and transverse slit at end through which fascia strip is passed.

FASCIA GRAFTS

Transplantation of fascia was introduced by Kirschner (1909) It has received widespread acceptance in bridging hernial gaps in reconstructing facial and other muscular palsies and tendon defects and in closing defects in such regions as the trachea esophagus and diaphragm it is also used in arthroplasties to prevent ankylosis and serves as living suture material Fascia is easily obtainable. It is extremely resistant to infection and adapts itself readily to the mechanical requirements of the surroundings—factors which make fascia an excellent material for transplantation

Technic: The best source of fascia grafts is the fascia lata. The simplest way of removing strips of fascia is with a fascia stripper (Fig 27)

Hip and knee are bent, and the extremity is rotated inward. From a small transverse incision at the lateral surface of the thigh above the knee joint, the fascia lata is exposed. A small strip of fascia of desired size is outlined with the knife, it is fed through the opening of the stripper, and then grasped with a hemostat and held taut. The stripper is now moved upward, cutting and separating a strip of fascia of desired length. If the stripper is provided with a cutting mechanism, the upper end of the graft is cut, otherwise, it is separated with the knife from a separate small incision. Graft and stripper are removed through the lower incision. If several strips are needed, the graft may be divided or other grafts obtained from the same incisions. Herniation of muscles after this procedure has not been observed by the author. If broad pieces of fascia need to be removed, the fascia must be exposed from a longitudinal incision through skin and fat tissue along the lateral surface of the thigh. The desired piece of fascia is freed from the overlying fat tissue, and then removed with the scalpel. Traction sutures at extreme points of the graft facilitate removal and the marking of boundaries.

Concerning transfer, fixation, and postoperative treatment, the reader is referred to Case 15, p. 866.

STRIATED-MUSCLE GRAFTS

Free transplantation of striated muscle proves to be of little clinical value except for hemostatic purposes (see p. 22).

TENDON GRAFTS

Tendon grafts are mainly used to replace tendon defects or diseased tendons. It is an established fact that, in selected cases under the proper operative and postoperative care, a tendon graft regenerates and functions. If the defect is due to infection, one ought to delay the operation for three months. Penicillin should be administered two days preoperatively and continued for at least four days postoperatively.

For the bridging of tendon defects, various autogenous or homogenous tissues, such as fascia, cutis, tendon, and even heterogenous material such as paraffined silk, have been recommended. Among the pioneers of this work are Kirschner, Bier, Lexer, E. Rehn, Lange, Bunnell, Koch, Mason, Mayer, and Iselin. According to the present consensus, autogenous tendon tissue is favored as graft material (May). The graft sources are the palmaris longus, the long extensor tendons of the fourth and fifth toes, and—under certain circumstances to be mentioned later—the flexor digitorum sublimis tendon.

Importance of Paratenon: In all tendon-grafting, aside from the regeneration of the tendon tissue, the role of the gliding tissue is of inter-

est and importance This tissue called paratenon is a loose, fatty meshwork rich in elastic fibers The paratenon provides not only the gliding mechanism but also the bulk of the nutrient vessels and nerves of the tendon The tendon sheath is a closed sac containing fluid It is found whenever the tendon changes its direction and serves as a fluid buffer to diminish friction at this point. The sheath consists of a parietal and a visceral layer Both layers are connected with each other by the mesotenon which carries the nutrient vessels and nerves Thus it becomes evident that a tendon graft has little chance to survive and to function unless the gliding tissue of the host area is preserved or if absent the gliding tissue is also transplanted Hence if the paratenon or the tendon sheath of the graft bed is absent, a paratenon-covered tendon graft must be transplanted So for instance in using one of the long extensor tendons of the toes as a graft, great care should be taken to preserve the loose areolar tissue which surrounds the tendon. It should be not only preserved but firmly held in place with a temporary suture at the extreme end of the graft. The paratenon like the periosteum of a bone graft, gains quick access to the circulation of the surrounding tissue and is able to reestablish the interrupted blood supply within the tendon graft. That intratendinous vessels do exist is beyond any doubt (Mayer Edwards Brockis) If the paratenon of the graft cannot be preserved the graft must be taken from other sources as a free graft and wrapped around the tendon graft. The paratendinous tissue differs from ordinary fat tissue It is a loose areolar fat tissue which is found over the triceps tendon or directly over the fascia lata or in the interspace between the fascia lata and the muscle fascia.

Regeneration of Tendon Graft Opinions still differ concerning the manner of regeneration of a tendon graft. One group of investigators believes that the graft is replaced by fibrous tissue which is derived from the surrounding tissue. Another group believes in a true or at least a nearly true regeneration of the tendon graft, coming from the paratenon or due to metaplasia. All agree that the functional stimulus promotes quicker and better regeneration Whatever the manner of regeneration, it has been sufficiently proved experimentally as well as clinically that a grafted tendon segment under proper operative and postoperative care, can regain function to transmit the contractile force of its muscle. For technic and after treatment, the reader is referred to pp 729–734 and to Cases 151–154 pp 1055–1058

BLOOD-VESSEL GRAFTS

Transplantation of blood vessels became possible only after Carrel and Guthrie at the turn of the century had developed an adequate

Many successful cases of autograft vein transplants have been de scribed since that time (Murray and others) There is general agreement that autografts (veins) are more desirable than homografts and should be used in bridging peripheral arteries. But when dealing with larger arteries particularly *with the aorta autografts of proper size* are not available, hence one must resort to arterial homografts or heterologous material

The fate of an arterial homograft is of interest. It was first described by Carrel and later in detail by Klotz, Permar and Guthrie in 1923 (1) rapid degeneration of the intima within forty-eight hours and regenera tion of endothelial cells by growth inward from both ends of the graft (2) gradual replacement of muscle cells of the media by collagen fibers but persistence of elastic fibers for many months (3) surrounding of the grafted segment by a layer of granulation tissue replacing degener ated cells with connective tissue Swan Gross and Peirce and others confirmed these findings and came to the conclusion that all cellular layers in the graft are destroyed by host reaction that the elastic tissue of the media, however persists for several years, and hence that the host builds a new blood vessel on the scaffold of the elastic tissue of the graft McCune and co-workers studied the nutrition of blood vessel grafts They could demonstrate that practically all of the circulation reaching the graft walls is derived from surrounding structures and to a small extent from the anastomosis of the graft ends No vessels could be demonstrated en *tering the graft walls from the lumina.* Nevertheless in cellophane wrapped grafts the histological appearance of the layers immediately sur rounding the lumen was more normal than that of the outer media and adventitia indicating presumably that *some nutrition filters through the* endothelium from the lumen to supply the internal and medial coats It therefore seems important in the employment of arterial grafts that to promote vascularization the transplants be surrounded by as much vascular tissue as possible

A major problem relating to the clinical use of arterial homografts is that of availability and storage. According to Swan the grafts must be obtained sterile from young persons from two to thirty five years of age previously in good health whose death is sudden or from a relatively acute cause The vessels must be obtained within six hours post mortem The problem of storage is equally important. It has been clearly dem onstrated by Gross and his group (Peirce) that viably preserved vessel grafts are more reliable and give better functional results than nonviable vessel segments *They behave for a while like* autogenous grafts Hence,

viably preserved grafts should be used. Two methods of storage are available: cold preservation and lyophilization. The latter has the merit of simplicity, but has not gained popularity, mainly owing to lack of large-scale evaluation. Deep freezing (Hufnagel, Deterling, Swan), as well as quick deep freezing (R. B. Brown, Kremer) in a nutrient solution as medium and storage of the graft, has been shown to be successful, but storing grafts in a stoppered bottle containing a balanced salt solution and 10 per cent plasma or serum at 4° C. is simpler, and accomplishes the same aim for periods up to about forty-five days (Peirce). Swan and Sauvage and Harkins believe that Ringer solution is equally efficient. This subject is broadly discussed by Lehr and Blakemore.

Technic: Swan summarizes the details of the operation as follows. Suture anastomosis is best suited for insertion of the graft. This may be done by temporarily controlling blood flow proximally and distally with noncrushing arterial clamps, such as Poth's serrated clamps during the anastomosis, or if preservation of blood flow during the procedure is essential—for example, in the carotid artery—the technic of minimal interruption over temporarily placed polyethylene tubes may be employed. All the niceties of technic of vascular suture must be meticulously observed—strict asepsis, avoidance of tissue injury by trauma or desiccation, careful stripping of the adventitia, careful placement of small atraumatic sutures, and careful wound closure without dead space or necrosis. In addition, the employment of a graft of proper size is of paramount importance. The lumen of the graft, when distended by the blood pressure, must match as exactly as possible the lumen of the recipient vessel, thus forming a vessel in continuity of uniform or tapering caliber.

If these precautions are observed, concludes Swan, anticoagulant drugs need not be used unless blood flow has been interrupted for more than an hour. If interruption has been prolonged, thrombosis of the distal artery may occur, and heparin should be used to limit the spread of these distal thromboses.

Linton and Menendez maintain that the end-to-end anastomosis, in many instances, causes a slight stenosis with a chance of subsequent thrombosis. To counteract this, they recommend the end-to-side anastomosis (Fig. 28), modified after the original technic of Kunlin of Paris. With this type of anastomosis, there is a widening at both the end of the graft and the host artery itself, thus reducing the chance of stenosis and secondary thrombosis. They also recommend, while preparing the graft, to rinse it frequently with an 0.01 per cent solution of heparin and to soak it in this solution before it is actually inserted and to inject about 20 cc. of

the same solution into the stumps of the host arteries distal to the distal occluding clamp and proximal to the proximal clamp

If an autogenous vein graft is used, the same meticulous care must be observed A tourniquet should be used if possible if it is contraindi

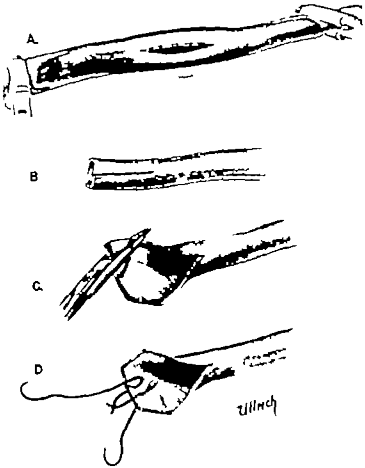


Fig. 28a: An artist's drawings to demonstrate the end-to-side technic of an arterial anastomosis. (A) A longitudinal incision is made in a section of the host artery isolated between two bulldog clamps. For most arteries it is two to three times as long as the diameter of the vessel. (B) A longitudinal slit is made in the cleanly divided end of the homograft, approximately equal in length to the incision in the host artery (C) The corners of the square-ended arterial flap are trimmed. (D) The anastomosis is commenced with two mattress sutures, using two arterial sutures tied together They are placed in the center of the arterial flap and also at the apex of the incision in the graft. The former is shown, and note that the needles have gone through the graft wall from outside to inside. (Linton, R. R. and Menendez, C. V Ann. Surg.)

cated or impossible the vessel stumps are closed with noncrushing arterial clamps such as Poth's serrated clamps which are applied a few centimeters above the wound edges The vena saphena cephalia or vena jugularis externa is used as a graft, or if the corresponding vein of the artery to be grafted must be tied a section of this vein should be trans

planted The graft should be handled with the greatest care. It should be transplanted in opposite direction to the blood stream to overcome the valvular mechanism The graft should not run through a dead space Carrel's suture technic is used (Fig 29) If the grafted vein has a much

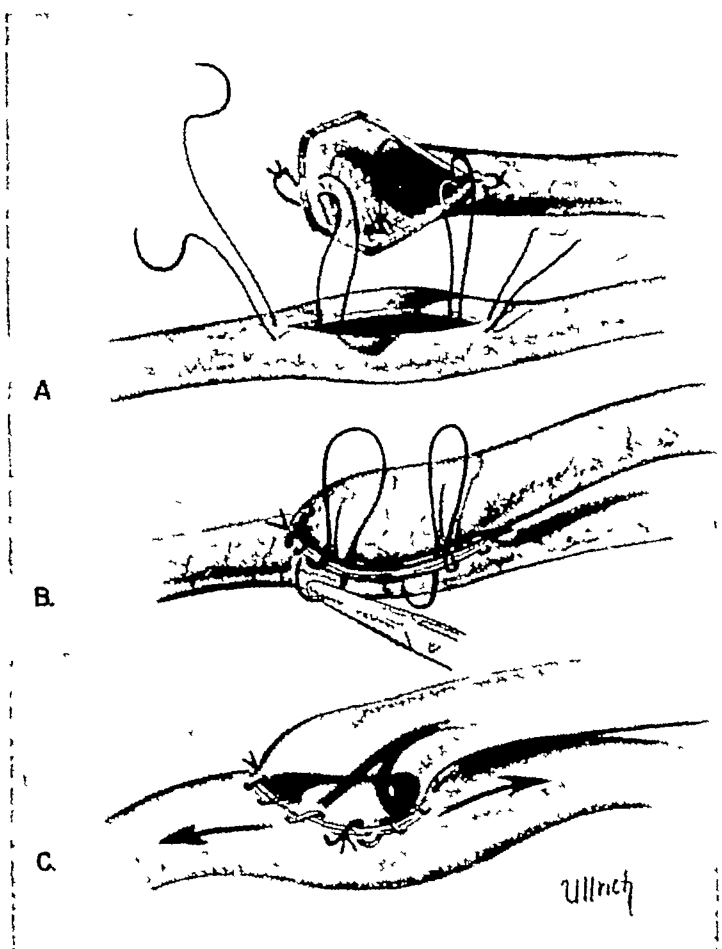


Fig 28b. The end-to-side technic (continued) (A) The two mattress sutures have been placed Note that the needles have gone through the host artery from inside to outside, to prevent loosening and fragmenting the atheromatous intima (B) The mattress sutures are tied, then commencing at each end they are used to continue the anastomosis with a simple running over-and-over type of stitch This everts the edges to give an intima-to-intima approximation, and it is also hemostatic. (C) To complete the anastomosis the two ends of each are tied together where they meet in the center of the suture line on each side As indicated by the arrows, the blood will flow both proximally and distally in the host artery with this type of anastomosis (Linton, R. R and Menendez, C V Ann Surg)

smaller lumen than the artery, an everting mattress suture (Dorrance) is preferable to a simple overhand stitch (Fig 29 lower row) It secures a better adaptation of the lumina, a better hold of the tissues, and consequently a better approximation of the intima The end-to-side anastomosis (Fig 28) may prove still better The extremity should be elevated to heart level or to a slightly dependent position (see p. 602) After the

wounds are sutured immobilization is carried out on a molded plaster cast or wooden splint The first dressing should not be changed for about two weeks if possible The patient may be permitted to walk after three weeks

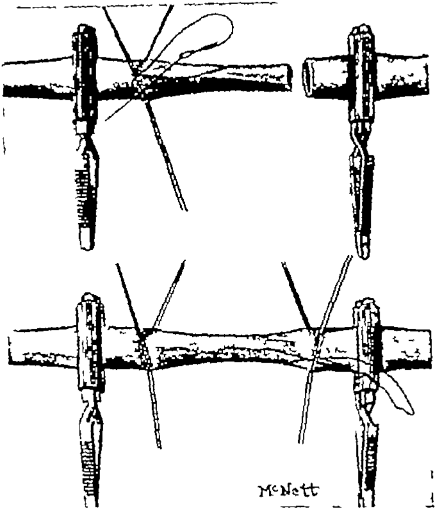


Fig. 29 Section of vein grafted to bridge defect in artery Arterial stumps are closed with elastic arterial clamps. *Upper row* Carrel's technic. Three traction sutures are placed at equal distance through entire wall of vessels. If traction is applied, round circumference of vessel becomes triangular thus facilitating suturing, in which finest arterial silk is used in continuous overhand stitch under eversion of intima. *Lower row* Dorrance's everting mattress suture, used when grafted vein has much smaller lumen than artery After completion, a second row of simple sutures (*left*) secures everted edges.

Blakemore and Lord introduced a nonsuture method of blood vessel anastomosis with the aid of vitallium tubes The suture anastomosis however is simpler and has remained popular

Anticoagulants Administration of anticoagulants may or may not be necessary as already pointed out. If their use becomes necessary the choice lies between heparin and dicumarol Heparin was discovered by McLean and finally purified by Best, Charles and Scott dicumarol was

introduced by Link and co-workers Heparin found in animal tissues is an antiprothrombin and antithrombin as well, it also seems to activate naturally occurring inhibitors of coagulation in the blood It decreases the coagulability of the blood and hence prolongs the coagulation time Dicumarol is the active principle in spoiled sweet clover, it acts as a biological antagonist to vitamin K, hence as a suppressor of prothrombin synthesis by the liver, thus lowering the prothrombin level in the plasma. This effect is normally reversible by vitamin K administration Heparin is administered parenterally, dicumarol orally Heparin acts immediately upon entering the blood stream, dicumarol after twenty-four to forty-eight hours The return of the clotting mechanism to normal following discontinuance of the two drugs is rapid with heparin and delayed with dicumarol Hence, daily prothrombin determinations are necessary when dicumarol is administered, while simply performed clotting-time determinations may be sufficient after heparin administration Dicumarol is strictly contraindicated in severe liver disease, and should be used with caution or not at all in all conditions where, in the event of bleeding (after recent operation), reversal of its effects may take considerable time Both drugs may also be used combined (Rhoads and coworkers), here, dicumarol seems to enhance the effect of heparin An outline of the modern concepts of blood coagulation is collectively presented by Salibi, by Quick and Halse, and by Shapiro and Weiner

Heparin There are two ways of administration which are generally recommended the continuous infusion route (Toronto method), as recommended by Murray, and the intermittent (Swedish) method, as recommended by Crafoord and Jorpes, Bauer As Duff et al. point out, the choice of the method may be partly resolved by recognizing that varying circumstances should determine the modality employed If the continuous intravenous method is used, an appreciable period may be required before adequate prolongation of the clotting time occurs This disadvantage can be met by injecting from 50 to 100 mg of heparin in the rubber tubing

CONTINUOUS INTRAVENOUS ADMINISTRATION A variable quantity of the drug (from 100 to 200 mg) is mixed with 1000 cc of glucose or saline, as Duff advises This is administered until there is a measurable increase in the clotting time, tests being made every two or three hours until the rise is detected The infusion is then slowed down to about 20 drops a minute, adjusted according to the effect on the clotting time, and checked thereafter about twice a day. Clotting-time values are usually prolonged from fifteen minutes to less than thirty minutes

INTERMITTENT INTRAVENOUS ADMINISTRATION This is advisable when

rapid action of the drug is required. Bauer recommends the following schedule 50 mg of heparin injected intravenously every four hours during the day and 100 mg at midnight. If rapid interruption of the action of the drug becomes necessary protamine sulfate is a valuable and quick-acting antagonist

Dicumarol Dicumarol is administered either daily or by the so-called discontinuation-dosage method (after Shapiro pioneer in demonstrating the remarkable therapeutic effectiveness of the drug)

DAILY ADMINISTRATION An oral dose of 300 mg of dicumarol is given the first day followed by 200 mg on the second day the dosage is controlled thereafter by daily determination of the prothrombin time which should be kept at two or three times normal

DISCONTINUATION DOSAGE By this method, the first dose is large enough to ensure elective prolongation of prothrombin time It starts with a minimum of 300 mg up to 1000 mg unless there is a suspicion of liver disease or a state of poor nutrition This initial dose may be divided into two doses about twelve hours apart. No further dicumarol is given on the immediately subsequent days the prothrombin time is checked daily When the downward trend is definitely established another single dose is given This dose is rarely as large as the initial one but is large enough to provide undoubted effectiveness—seldom less than 200 mg Again the prothrombin time is followed daily until it begins to fall and the single large dose is repeated. This series of single doses followed by prothrombin time prolongation and partial restoration of prothrombin level is repeated as long as the anticoagulant therapy is indicated

If rapid interruption of the action of the drug becomes necessary or if the prothrombin time should continue to rise on the fourth or fifth day after the initial dose the reaction must be considered abnormally prolonged and vitamin K should be given as a precaution Vitamin K should be given in massive doses of from 50 to 100 mg intravenously If there is actual evidence or indication of serious bleeding, the prothrombin can be restored by administration of whole blood

NERVE GRAFTS

Transplantation of nerves was for a long time a discouraging subject but since Duel and Ballance s (1932) demonstrations of successful nerve transplantation in facial palsies much interest in this subject has been aroused among surgeons The first thorough information about the degenerative and regenerative processes following nerve transplantation was given by Huber (1895) Many more studies have since been published (Eden L. Davis and co-workers Klar and others) and although more

light has been thrown upon this subject, particularly recently (by the experimental work of Sanders, by an extensive clinical research study of Seddon, and by the histological observations of Holmes), agreement is far from complete. Most investigators believe that autotransplants are more reliable than homotransplants or heterotransplants. If a nerve becomes separated, the peripheral end undergoes degeneration, resulting in atrophy of the axis cylinders. If the nerve continuity can be restored—and even wide gaps may be closed by favorable displacement of the central and peripheral stumps (Babcock)—the axis cylinders of the proximal end may grow downward into the peripheral end and regenerate the nerve. If, however, the gap between the severed nerve ends is so wide that direct suture is not possible, a section of another nerve may be transplanted to bridge the defect. This graft undergoes the same degenerative changes as the peripheral end of the severed nerve, but may provide the channels along which the axis cylinders of the central end grow to reach the peripheral end.

Whether to use a graft of a motor or a sensory nerve apparently does not make any difference. But there is no agreement on whether fresh or degenerated nerve grafts should be used. However, according to recent reports (Bentley and Hill, Bunnell and Boys, Young, Holmer and Sanders), fresh—not degenerated—autografts are likely to provide the best results. Some authors recommend glue (coagulated plasma, acacia) to replace sutures of the severed nerve ends (Young and McDavar, Klemme, Woolsey and Regende). Some advise sutures and coagulated plasma (Bateman). The success of nerve-grafting depends much upon the time that has elapsed since the original nerve injury and upon the skill of the operator. In many cases, nerve-grafting must be preceded by replacement of excessive skin scars with pedicled flaps.

Technic: The ends of the severed nerve are exposed by an adequate incision, a tourniquet should not be used, since it may interfere with later regeneration. Thorough hemostasis is of the utmost importance. The dissection of the nerve ends should not be carried too far, and should be as gentle as possible. All scar tissue at the stumps is removed. This is done with a sharp knife by cutting small slices off until normal fibers are exposed. After thorough hemostasis, the wound is covered with gauze soaked in warm isotonic saline solution. (For exposure and handling of the nerve ends, see also p. 590.) The graft is now removed. The aim must always be to implant a graft or a collection of grafts having a total cross-section equal, at least, to that of the peripheral stump of the damaged nerve.

Since, according to experimental and clinical experience, sensory

nerve grafts are capable of conveying motor responses, it is not necessary to sacrifice a motor nerve for obtaining a graft. The nerves which are commonly used as grafts are the nervus saphenus and the nervus cutaneus surae medialis The former accompanies the vena saphena magna and is exposed on the median aspect of the leg on the level of the tuberositas tibiae The latter accompanies the vena saphena parva and is found in the midline of the calf beneath the deep fascia in the upper half and superficial to it in the lower half Of other nerves to be considered for graft material are the superficial radial nerve between elbow and wrist, and the nervus cutaneus antibrachii If the nerve to be bridged has a small caliber one section of the sensory nerve is used as a graft.

The graft is handled as gently as possible. Neither the recipient nerve nor the graft should be grasped with forceps The wound should be kept moist constantly Fine silk and needles are used. The fibers of the graft and recipient nerve are brought in close approximation and are held in this position by accurate suturing of the epineurium care being taken to prevent inversion of the latter

If the nerve to be bridged has a large caliber several sections of nerve grafts are taken and sutured together until a cable is formed (Elsberg) Accurate fixation of cable grafts with sutures may be very difficult. For this reason L. Davis recommends the use of fresh homogenous nerve grafts which others consider doomed to failure To overcome the suture difficulties of a cable graft the plasma suture is here of great value (Tarloff Young and Medavar Seddon) Seddon advises the following technic. The field of operation must be dry The grafts are laid in position and the ends accurately apposed to the cut surface of the stumps Provided that the grafts have not been moistened with saline, it will be found that they are sufficiently tacky to adhere slightly to the cut surface of the stumps The operating room table is then manipulated in such a way as to make the bed of the graft a horizontal lake. Bone wax or fibrin foam may be used (they are removed later) to build up any deficiency in the site of the lake so that it will form a convenient receptacle for the plasma It has not been found convenient to use the plasma-suture molds devised by Tarloff (1944) An assistant then drops the prepared plasma from a fine pipette onto one junction while the surgeon concentrates his attention on the line of suture. He may find it necessary to hold one or more grafts in position with watchmaker's forceps which can be withdrawn without disturbance after the plasma has clotted. A second batch of plasma is then prepared and used for the distal suture line In order that the grafts may acquire an adequate blood supply from the

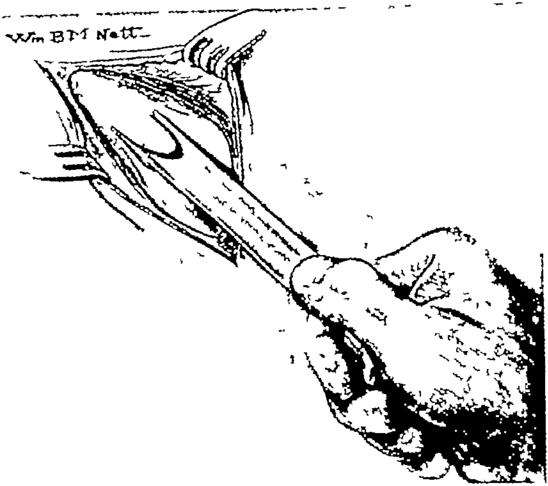


Fig 30 Removal of cartilage graft. From incision over right costal margin, rectus sheath and muscle are split and retracted. Fused cartilaginous portion of seventh and eighth ribs are exposed and area to be excised is circumscribed with an incision. Graft is removed with a gauge, which is pushed forward with rotary movements.

mammaria interna pleura or peritoneum The desired portion of graft can now be removed with a knife or a pair of strong scissors from the costal margin One may use Doyen s rib shears and resect a section of rib cartilage similar to resecting a piece of the bony part of the rib The graft is wrapped in a piece of gauze soaked in warm isotonic saline solution The donor area is closed after insertion of a drain

To shape the graft it is placed on moist gauze and trimmed with a sharp knife to the desired form If some of the material is left over and a subsequent operation is necessary it can be stored for further use by inserting it beneath the skin of the abdomen

For transfer and after treatment the reader is referred to special examples (Cases 50 51 52 75 pp 915 916 917 944)

Diced Cartilage Grafts. Peer in repairing defects of the skull and other depressions, used autogenous cartilage grafts which are cut into many fine squares or cubes The small grafts are introduced into an

exposed depression of the skull, for instance, and gently patted into a rounded contour, the skin of the scalp is sutured over the rounded surface of the cartilage mass This method has an advantage over the use of large segments of cartilage grafts—the larger grafts, after approximately two months, cause irregularities which may become noticeable and require repair, whereas the diced grafts lend themselves to smoother molding The small grafts regenerate as well as large grafts This method is recommended to fill depressions which require firm support, such as of skull, orbital region, and mastoid after extensive mastoidectomy Peer also used diced cartilage grafts to form the framework of the auricle in its reconstruction He made an exact model of the patient's other ear, from which a perforated vitallium mold was made The mold was filled with diced cartilage grafts and buried beneath the abdominal skin Connective tissue grew through the perforations After three months, the mold was removed, and the grafts were found bound together in the form of a perfect ear.

Bank Cartilage (Brown and McDowell): The material is from postmortem examinations in young adults whose serological analyses of the blood are negative The cartilage is removed under sterile technic The numerous sources are the costal cartilages from the angles of the sixth and seventh ribs All soft tissue and perichondrium are dissected off

The cleaned cartilage is placed in a sterile glass jar containing 1 1000 aqueous merthiolate (or 1 1000 merthiolate in isotonic saline solution) and kept in refrigeration at 4° C for one week with the jar sealed At the end of this time, a few chips of cartilage are cut off with sterile instruments and cultured The solution is poured off, replaced with 1 5000 aqueous merthiolate (or 1 5000 merthiolate in isotonic saline solution), and returned to the refrigerator At the end of the second week, the cartilage is again cultured If both cultures are negative, the cartilage is ready for use Cultures are repeated every week, and the cartilage may be used up to one year or possibly longer after removal If any culture is positive, the whole jar of cartilage is discarded

BONE GRAFTS

Bone grafts are used for healing nonunions, bridging bone defects, and filling other defects in which rigid support is required. The ordinary sources are the anterior surface of the tibia, the crest of the ilium, and, in rarer instances, a section of the fibula and a rib Sometimes a sliding bone graft is used, the source of which is the bone from the immediate neighborhood of the defect (see Figs 342–344)

Regenerative Processes Of all the tissues used for transplantation,

none has been more discussed concerning regeneration than bone (May) The consensus is that a bone graft unlike most other tissue grafts does not survive after its transplantation it dies at least its osteocytes disappear The periosteum however if the graft transplanted was covered with it, may remain alive Within a few weeks vessels grow into the dead graft from the transplanted or host periosteum and from the host bone these vessels are accompanied by periosteal and endosteal osteoblasts which transform the dead bone into living bone (Figs 31 32) Although the validity of this belief has been questioned ever since Ollier of France first postulated it, it never has been totally disproved (Lexer Axhausen Siffert) However according to recent investigation (Mowlen Abbott Ham and Gordon and others) Ollier s original theory needs modification It seems that in a cortical bone graft the entire graft does not die but parts survive that in a cancellous graft, most of the cells survive if in contact with vascular tissue regardless of whether transplanted on like or unlike tissue whether transplanted with or without periosteum Others (Peer et al) could not verify these findings (survival of bone grafts in unlike tissue) Another group of investigators (Marchand, Bier Horwitz Lacroix) believe that a bone graft is regenerated by immigrating connective tissue cells which undergo differentiation and change into osteoblasts All however agree that an autogenous bone graft transplanted on living bone has the best chance of regeneration even if the entire graft should die (For additional references see articles of May and of Nicoll) That the bone graft dies and does not become regenrated per se but from the surrounding osseous regenerative tissue explains the fact that homogenous and even heterogenous grafting may lead to organic union Autogenous bone grafts however are more reliable and are regenerated quicker than homogenous grafts.

Hence the best results may be obtained by using autogenous periosteum and endosteum-covered grafts by quick establishment of the interrupted circulation of the graft and by prolonged complete immobilization (see p 635 and Cases 119 120 121 160 pp *1012 1013 1014* 1066) The pattern of revascularization of bone grafts has been described in detail among others by May and by Stringa

Technic: The operation begins with preparation of the host bone The incision through the skin is curved so that the subsequent scar will not encroach upon the graft A tourniquet should not be used. All the bleeding points should be ligated so that the wound is absolutely dry otherwise hemorrhage prevents the first adhesions between soft tissue and the periosteum-covered graft. When the bed is exposed a careful examination for cicatricial tissue is made It must be completely removed.

because white, glassy tissue is an obstacle to vascularization The space in the host bone which receives the graft must be prepared so that the entire surface consists of healthy, bleeding bone and medullary tissue

Removal of Graft from Tibia An incision is made along the lateral crest of the tibia The incision curves mediad, and crosses the anterior

a b

Fig 31 Vascularization of bone graft (experimental study by the author) *a* Distal section of reimplanted radius of a dog ten weeks after operation Vessels have been injected with turpentine-mercury solution through arteria axillaris Beginning of vascularization and regeneration (compare with Fig 32) *b* Another specimen ten months after operation Complete reestablishment of circulation Graft is regenerated

surface of the tibia in its lower portion The skin is separated from the periosteum if the graft is to be transplanted covered with periosteum, otherwise the periosteum is left attached to the skin, and stripped off the bone with a periosteal elevator The area to be excised is circumscribed

with an incision The graft is excised either with chisels or with a motor driven saw The latter has the disadvantage of producing heat and the author uses the saw only to outline the graft while the actual removal is with chisels and mallet (Fig 33) The graft is wrapped in saline-soaked gauze for the time being The donor area is closed. A gauze roll is fitted into the depressed donor area and a compression dressing is applied Immobilization may be necessary depending upon the size of the bone defect.

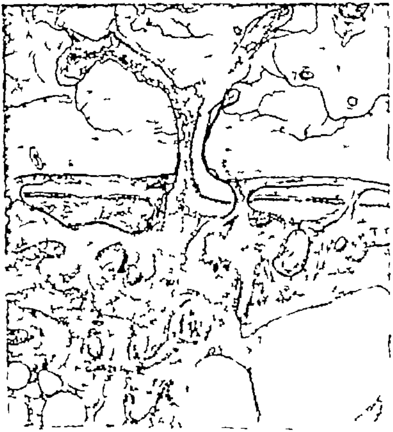


Fig. 32: Histology of bone graft. Section of grafted bone ten weeks after operation (see Fig. 31 a) Cortex is still dead lacunae are empty but trabeculae have been transformed into living bone tissue by osteoblasts, which, accompanying the vessels through the haversian canals, can be seen in their bone-substituting action.

Removal of Graft from Crest of Ilium An incision is made along the crest of the ilium commencing just below the spina iliaca anterior superior The soft tissues are split on the crest and dissected away from the lateral and median surface of the bone The graft, consisting of the entire thickness of the crest is removed with a small (metacarpal) saw During the sawing the soft tissues are protected by holding them away with wooden boards, similar to those used for stretching the skin to remove

split grafts (Fig 34) A drain is inserted into the wound, which is then closed in layers

Removal of Graft from Median Surface of Ilium Grafts from this area were introduced by Pickrell They are suitable for restoring loses of the skull, depressions of the cheekbone, etc They are easier to obtain and more adapted in contour and thickness for this particular purpose than grafts from the outer table of the ilium The median surface of

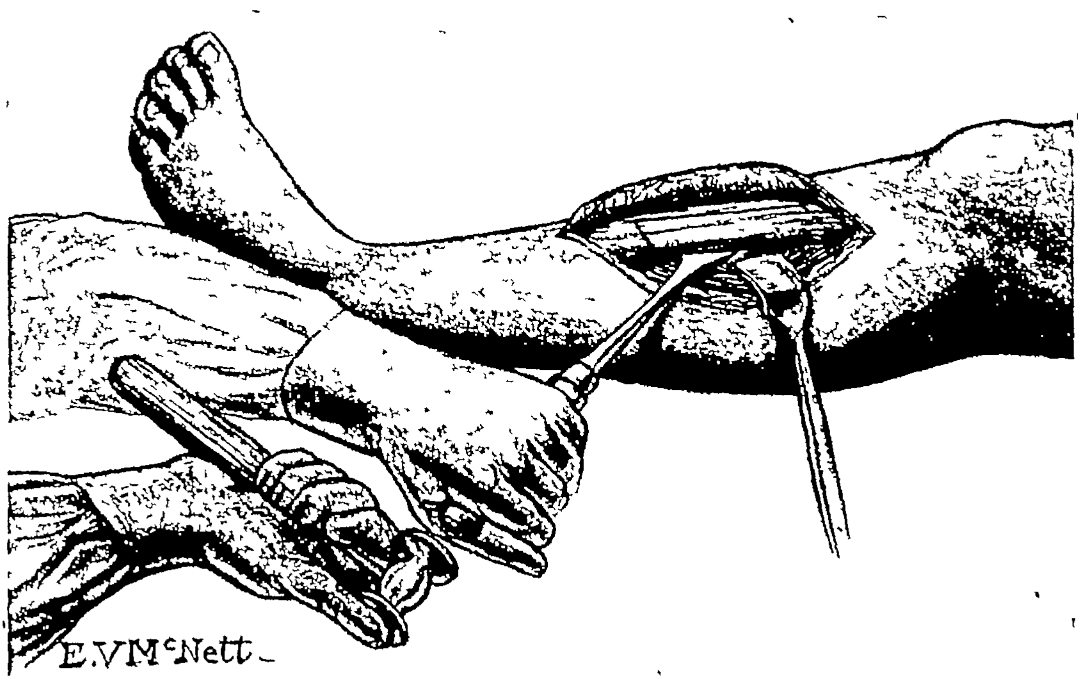


Fig 33 Removal of bone graft from anterior surface of tibia Median, proximal, and distal boundaries have been outlined with circular saw Mobilization of graft is completed from lateral border with chisels

the ilium is exposed from an incision along its crest The muscles are severed from it, and the musculus iliacus is stripped from the periosteum of the median table With long, broad retractors, the soft tissues are held mediad With a V-shaped osteotome, the selected part of the ilium is circumscribed with a groove The only difficult part is the outlining of the graft in the deep part of the pelvis I have used for this purpose a motor-driven saw with a small rotary blade Oscillating saws, if sufficiently small, would be ideal The graft is then removed with flat osteotomes, care being taken that the latter do not penetrate too deeply into the pelvic bone. There is considerable oozing from the graft bed, which is temporarily controlled with hot saline compresses The latter are later replaced with gelfoam Drains are inserted into the cavity and the wound is closed.

Removal of Graft from Fibula The fibula is exposed through an incision, as demonstrated in Figs 340–341 The soft tissues are dissected away from the bone care being taken not to injure the peroneal artery which at the median side is in close proximity to the bone The section of bone to be used is separated either with a costotome or with a Gigli saw If the

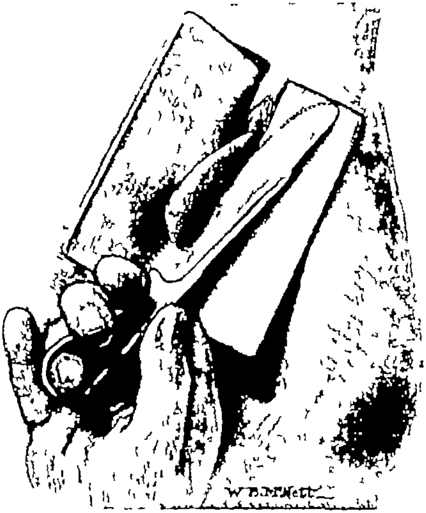


Fig. 34 Removal of bone graft from crest of ilium. From incision along crest, soft tissues are split, dissected from lateral and median surface of bone and held away with two wooden boards. Graft is removed with hand saw

graft is to be used without its periosteum the latter together with the soft tissues is stripped from the bone with Doyen s rib shears similar to those used in rib resection If the head of the fibula together with a section of fibula is to be used the peroneal nerve must be exposed and carefully held forward while the head of the fibula is detached from its ligaments (see p 628) The wound is closed after insertion of a drain

Removal of Graft from Rib From an incision along the rib (seventh) the fascia and muscles are split and dissected away from the bone The

an International Symposium on Corneal Surgery, sponsored by the Eye Bank for Sight Restoration, Inc This brings the status of this fascinating type of surgery up to date The symposium has been followed by several other publications (Castroviejo, Maumenee, Patan, Thomas, Rycroft et al, and others) Since it is beyond the scope of this book to discuss this special field of surgery, the reader interested in keratoplasty is referred to the publications mentioned

Transfer of Flaps

A flap is a portion of tissue which remains attached by one pedicle (single-pedicle flap) or by two pedicles (double-pedicle flap) to the circulation Flaps are indicated when skin and subcutaneous tissue need to be replaced A flap is either simple, consisting of skin and subcutaneous tissue, or compound, consisting of skin, subcutaneous tissue, and bone or cartilage These flaps may be lined by folding the flap upon itself or by transplanting a skin graft to that part of the flap which is to replace the lost lining (mucous membrane) The viability of every flap depends upon a sufficient arterial and venous circulation, which is supplied through the pedicle A flap can be taken from the immediate neighborhood of the defect or from distant parts. Flaps taken from the adjoining area of the defect have the decided advantage of tissue resemblance and quick healing. Flaps from distant parts may not have this advantage, but—as a rule—have more versatile use.

GENERAL PRINCIPLES

Planning and Mobilization of Flap: There are certain general rules that should be observed in flap transplantation In selecting the flap, the characteristic features of the skin surrounding the defect should be considered and the donor area chosen to accord in color, texture, and thickness A flap should be made one third larger than the defect to counteract shrinkage, unless it contains one of the main arteries, whereupon the flap can be made longer and the pedicle narrower Normal skin, free of cicatricial tissue, should be selected

Flap Taken from Immediate Neighborhood If the flap is to be taken from the immediate neighborhood, the sliding (French method), rotating (Indian method, Carpue), and turnover methods are available, and the flap is planned accordingly The *sliding-flap method* is similar to some of the methods of tissue-shifting, and has already been described (p 18, Fig 16) The principles of the *rotating method* consists in making the flap in such a way that the pedicle of the flap borders the defect while the flap itself is some distance from it To facilitate rotation and lessen the tension in the pedicle, the blind end of the incision should be

turned outward (Fig 35) (Dieffenbach von Langenbeck) (Cases 1 38 pp 841 898) In the *turnover method* the flap is to be hinged around its pedicle to replace a defect of nose or cheek whereby the skin of the flap is to replace the lining mucous membrane Covering of the raw outer surface of the flap must be provided for either by skin-grafting or by skin-sliding (Fig 69)

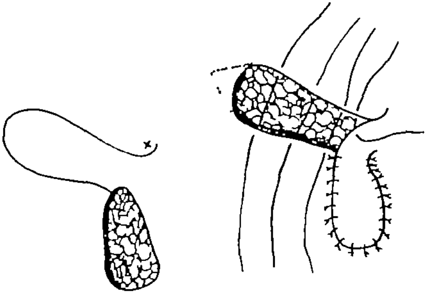


Fig. 35 *a* Closure of surface defect by rotating flap taken from immediate neighborhood into defect (Indian method) Pedicle of flap borders defect while flap itself is some distance away from it. To facilitate rotation, blind end of incision *(x)* is turned outward. *b:* Flap is rotated into defect, and donor area is closed by skin-sliding.

Flap Taken from Distant Parts If a flap is to be taken from distant parts (Italian method Tagliacozzi s method) it should be planned in such a way that it can be transferred by the least number of stages and fastened in a position which will not cause discomfort to the patient.

Pattern Cutting and Outlining The various flap methods require careful planning and outlining If possible the flap should come to lie along the axis of the circulation of the donor area. First a pattern is made of the defect The best material for this purpose is chamois but linen rubber sheeting or tinfoil may be used. The pattern is cut one third larger than the defect to make allowance for shrinkage of the flap The flap is now outlined in reverse to the planned operative steps (Gillies) The method for outlining a tube flap is demonstrated in Fig 41 but is similar for any other type of flap

In mobilizing the flap one should cut the flap with equal thickness This is easy at the scalp and other places where the subcutaneous fat tissue is thin and a firm layer of fascia forms the base But it is difficult in regions with well-developed fat pads.

Transfer of Flap. *Immediate Transfer*: Immediate transfer is understood to mean the mobilization and transplantation of the flap in one stage. It is only possible if the circulation is adequate, that is, if the color of the flap remains normal after the flap is raised. If there is the slightest doubt about the adequacy of the circulation—that is, if the flap becomes cyanotic or pale or its edges are not bleeding—it should be returned to its original site, and transfer should be delayed

Delayed Transfer Delayed transfer is understood to mean the mobilization and transplantation of the flap in stages. Mobilization in stages may become necessary to obtain an adequate blood supply Transplantation in stages may also become necessary because of the distance between the source of the flap and its final site

METHOD 1 The flap is raised and returned immediately to its original site (Perthes, Blair) Exact hemostasis is necessary to avoid hematomas beneath the flap. Drains should be avoided if possible If they are necessary, they should be inserted near the base of the pedicle The author has seen local necrosis where drains were inserted near the periphery. The dressing should be free of undue pressure Moderate pressure, however, is necessary After the color of the flap has returned to normal and all swelling disappeared (after two or three weeks), the flap is raised again As a rule, the line of cleavage can easily be found The flap may be ready for transfer Should the color of the flap change again, however, transfer should be further delayed

METHOD 2 Another method of delaying the transfer consists in raising parts of the flap in successive stages and each time returning the raised parts to the original bed, the stages being ten days apart

METHOD 3 Another way of delaying the transfer is by formation of a double-pedicle flap to be converted into a single-pedicle flap The various stages are described on pp 74–76 for the open double-pedicle flap and on p 78 for the tube flap

Methods of Transfer: There are two types of transfer: a direct and an indirect. The direct way of transfer is preferred, since it requires fewer stages than the indirect The *direct* method is possible (1) if a flap by its own length can be transferred to the defect (Fig 41, Cases 6, 14, 42, pp 860, 864, 904), (2) if the flap and defect can be approximated by favorable posture, whereby the host area is transferred to the flap (Figs 36, 39) (Cases 107, 109–111, 130–132, pp 994, 998–1002, 1028–1032) or the flap to the host area (Case 13, p 862)

The *indirect* method of transfer must be chosen whenever defect and flap area cannot be approached directly. It consists of transferring the flap by an intermediate carrier, usually the wrist or forearm (Fig. 47)

(Cases 11 106 pp 860 990) or by successive migration such as cater pillaring or waltzing

Fixation and Dressing of Flap After the flap is transferred and fitted into the defect it is fastened with sutures, which should not cause tension Whenever possible a row of subcutaneous sutures with cotton or catgut should precede the skin sutures All sutures are interrupted If a suture causes blanching of the flap edge it should be loosened or removed.

The dressing should be comfortable and free of undue pressure Even in places where the dressing is to keep the flap attached to a cavity like an empty orbit, the pressure should only be moderate. In flaps with long pedicles the dressing should support the pedicle The pedicle may be heavy and may tear the flap from its new position before becoming attached.

Whenever immobilization is needed to hold donor and recipient areas in proper position (flap and defect approximated by favorable posture [Fig 36]) a plaster cast provides the best fixation. Adhesive strips as a rule do not furnish sufficient support. The parts to be immobilized are well padded with layers of cotton The cast is applied in such a way as to provide sufficient support to keep the flap without tension. Neither the base of the pedicle nor the entire flap should be included in the cast (Fig 36) (see also Cases 109 111 129–130 170 pp 998 1002 1026-1029 1079)

Separation of Pedicle and Final Adjustment of Flap Unless the flap together with its pedicle is to be used for covering the defect, the pedicle must be severed. As to when a flap can be severed from its pedicle this depends entirely upon the extent of surface attachment of flap and host area Flaps attached only with one edge to the defect will need longer time to gain access to the circulation of the host area than those attached with a broad base The pedicle may be separated in one stage or in several stages. In either case, however the circulation must be tested before severance

Testing Circulation of Flap A few days before the pedicle is separated the circulation of the flap should be tested. The circulation running through the flap in the accustomed way *must be forced to run the* reverse way This is done gradually and various methods are available.

USE OF INTESTINAL CLAMP With a soft intestinal clamp the pedicle is compressed daily for several hours. The degree of pressure depends upon the change of color in the flap To demonstrate the adequacy of the circulation after application of the clamp the tip of a finger is pressed upon the flap (near the clamp) for a few seconds this leaves an anemic mark which—if the circulation is adequate—returns to normal color

TRANSFER AND FINAL SEPARATION OF FLAP For transfer and final separation of the flap from its pedicle, the reader is referred to p 70 As to the method of separation, the author prefers the gradual crushing of the pedicle with a laboratory clamp (Fig 39) The flap is adjusted in place after a few days

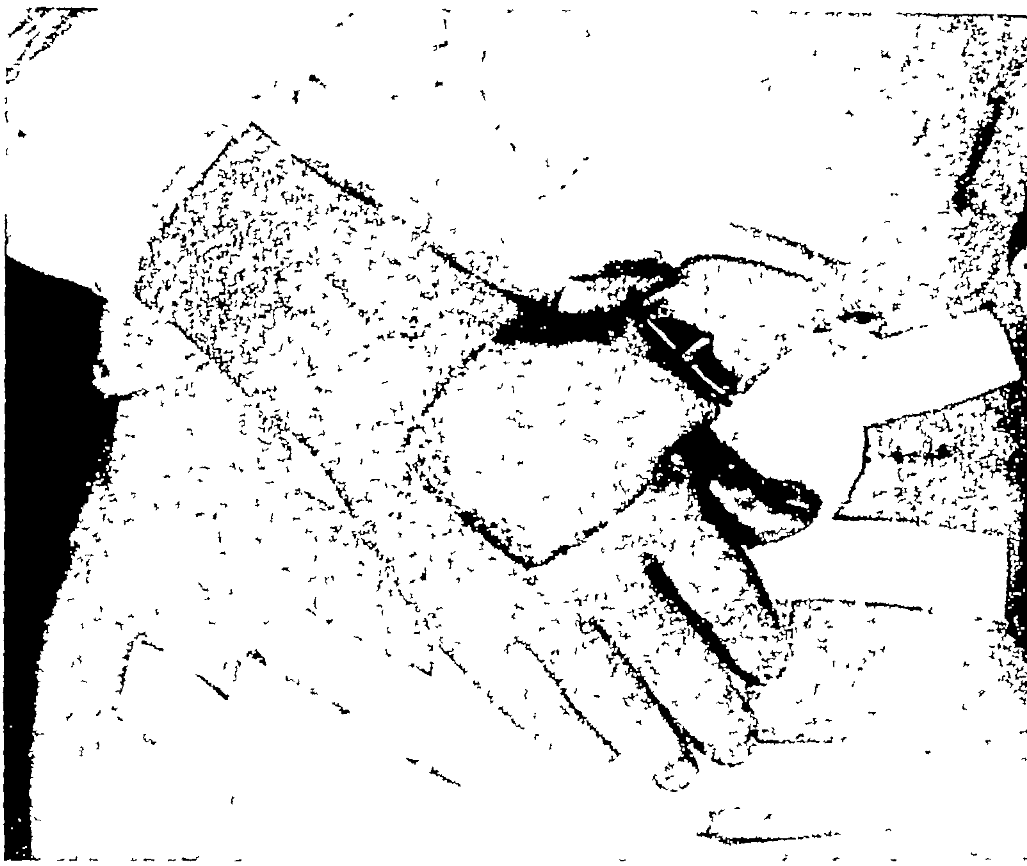


Fig 39 Separation of pedicle of flap, gradually performed by application and tightening of laboratory clamp

Open Double-Pedicle Flaps

The open double-pedicle flap is used as a pocket, or gauntlet, flap for repair of certain defects of hand or arm (Fig 40), or as a visor flap, which is a forehead flap pedicled in both temporal regions and brought down to cover defects of face and lips This flap, being attached by two pedicles, has an excellent blood supply, and hence can be cut thin and transplanted immediately

Procedure. The flap is raised and, if possible, the flap bed closed immediately by undermining the wound edges and skin-sliding. To refer to an example, the injured finger, with its injured dorsum (Fig 40), is placed beneath the flap of the abdominal wall. The wound edges of the

flap are sutured to the wound edges of the defect. The proximal pedicle of the flap is severed and adjusted in place after seven days. The distal pedicle is gradually severed after ten days by the laboratory-clamp method (Fig 39) followed by severance of the other end a few days later

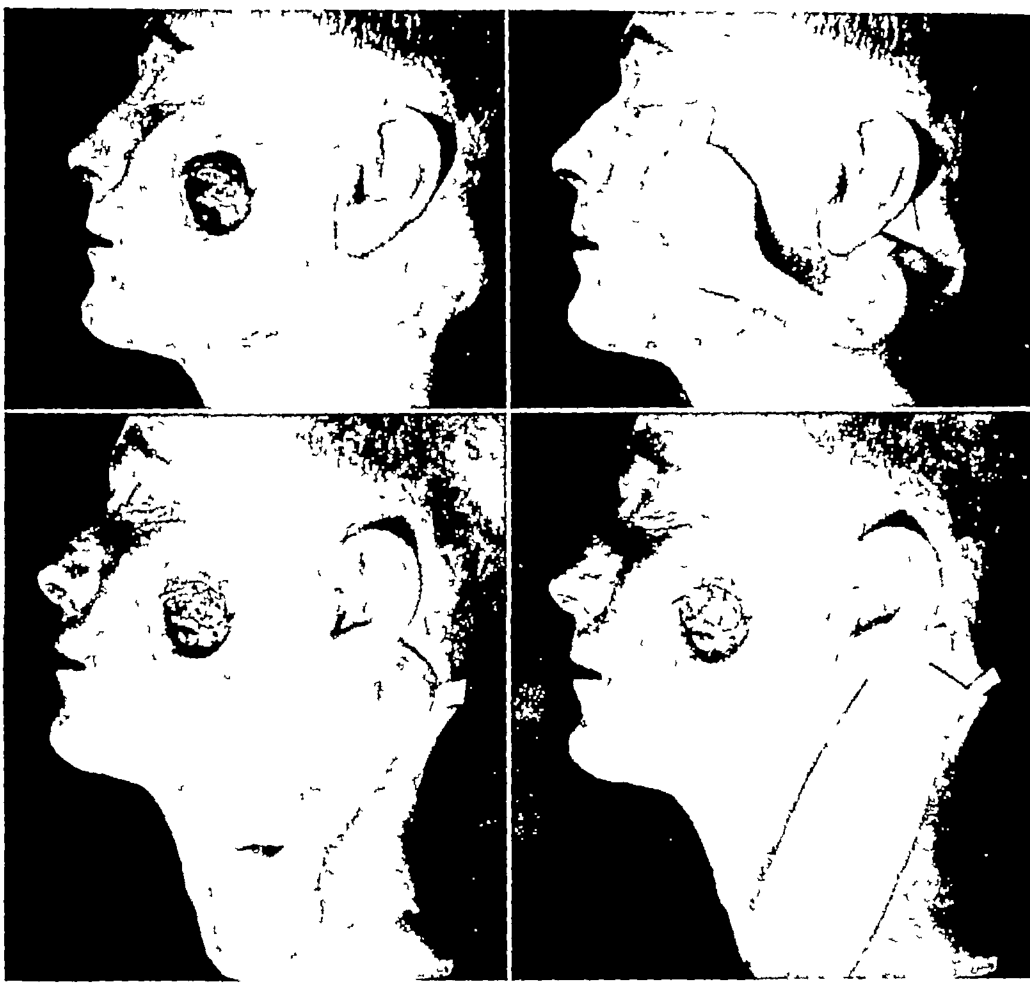
Large Pocket Flaps The pocket flap is excellent for smaller defects (Fig 40 Case 131 p 1030) In larger defects it has many drawbacks

Fig. 40 Open abdominal double-pedicle flap (pocket flap) covering surface defect of dorsum of left index finger

In large flaps the tremendous raw surface of the flap bed causes a great deal of drainage and is a constant source of infection Primary closure of the donor area by skin-shifting or skin-grafting has been unsuccessful in the author's hands Hence a large pocket flap should rarely be used but may be indicated for large transverse defects comprising either the entire dorsum or the volar surface of hand or arm (see Case 132 p. 1032) For dorsal defects it is taken from the same or opposite side of the abdomen and lower chest for volar defects from the back or less often the median side of the thigh of the same side In all cases in which only a part of the dorsal or volar surface is denuded a pocket flap is contraindicated since large parts of the flap—namely those lying on the uninjured skin of the hand—are not needed. They also add a source of irritation and

possible infection to the large raw surface of the donor wound In those cases, the open single-pedicle flap, as described previously (p 73), should be chosen in spite of the longer time needed for its preparation and transfer (Case 130, p 1028)

a *b*



c *d*

Fig 41, *a* Planning a tube flap to be transplanted from left cervical region to left cheek. Method is demonstrated on cast made of patient with cancer of cheek (see also Case 6, p 851) Various stages are reversed to those of actual transplantation *b* Piece of chamois skin is cut and tubed to cover defect and anchored in left mastoid region *c* Chamois tube is transferred to left cervical region *d* Tube is opened and spread flat.

TUBE FLAPS

The tube flap is a closed-flap method Hence, danger of infection and of scarring is minimized It is formed like an open double-pedicle flap at first It is converted into a closed flap by inverting and suturing the flap edges together The donor area is closed beneath the flap by skin-sliding or skin-grafting This type of flap was devised by Filatow, of Odessa, and Gillies, of London, independently in the same year (1917).

Gillies however deserves the credit for having popularized the method. Schuchardt of Hamburg has published a noteworthy well illustrated monograph on this subject.

Indications A tube flap is indicated whenever the open pedicle flap is contraindicated (see p 72) that is whenever—in using a direct transfer of the flap—defect and base of flap are some distance away from each other and whenever indirect transfer or successive migration is necessary to convey the flap to the defect.

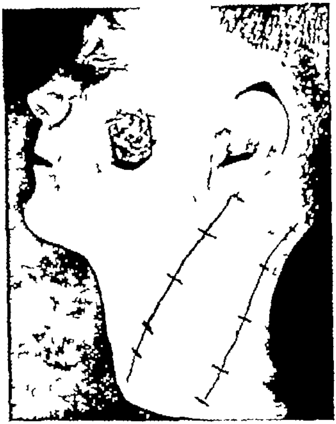


Fig. 41 *a* Width and length of flap is outlined on skin, and cardinal points of approximation of wound and flap edges are marked.

Planning and General Principles As in any other method of flap transplantation the flap should be carefully planned and outlined The flap should be cut so that its long axis comes to lie in the longitudinal direction of the circulation of the donor area. Therefore as a rule, it would seem inadvisable to extend the flap across the midline of the body, although no harm may result from doing this, as others and the author have found. In long abdominal flaps it is however safer to wait for one week before extending the flap across the midline when additional length is required As a rule a flap should not be more than 20.3 cm (8 inches) long and from 5 to 6 3 cm. (2 to 2½ inches) wide. In a vascular area and

with lean patients, flaps, however, can be made longer and narrower The planning and outlining of the flap is by pattern, and is done best in reverse to the actual operative steps (Gillies), as demonstrated in Fig 41 The flap is outlined along the pattern with an aniline dye To facilitate later approximation of corresponding flap edges as well as those of the wound edges of the defect, flap and wound edges are marked on each side in equal distance either by scratching the skin or by the intracutaneous injection of a drop of one of the aniline dyes (see Figs 41, *e*, 42)

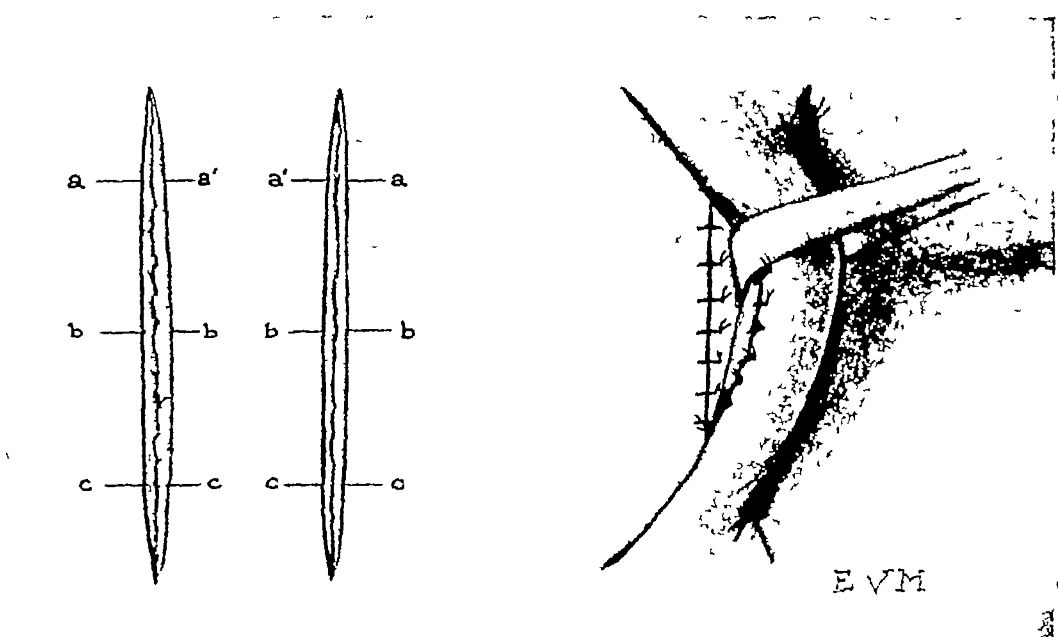


Fig 42 Construction of tube flap *Left* The flap, previously outlined and marked at cardinal points for later approximation of corresponding edges (Fig 41, *e*), is incised along its longitudinal edges Skin and subcutaneous tissue between the two parallel incisions are undermined *Right.* Flap edges have been inverted and cardinal points (*a'-a', b'-b', c'-c'*) sutured first, followed by closure of remainder of flap Flap bed has been closed by undermining wound edges adjoining donor area and skin-sliding with proper approximation of cardinal points (*a-a, b-b, c-c*)

Mobilization of Flap: The skin and subcutaneous tissue are separated with two parallel incisions along the lines drawn on the skin previously (Fig. 42) The depth of the incision depends upon the thickness of tissue needed for covering the defect As a rule, it reaches the deep fascia, and the flap includes the tissue between the deep fascia and the skin If, however, a shallow defect is to be covered, less subcutaneous tissue is needed But it is inadvisable to make the flap too thin On the other hand, if a thicker flap is needed, the flap should not be made too thick, since it may prevent closure of the tube The skin and subcutaneous tissue are undermined between the two parallel incisions After thorough hemostasis, the flap is now raised with a strip of gauze

Closure of Flap Bed The next step consists of wide undermining of the adjoining donor area to close the bed of the flap After thorough hemostasis with the flap held away by means of a strip of gauze the skin edges of the mobilized area are pulled together beneath the flap and fastened with sutures First sutures are subcutaneous sutures followed by skin sutures (on-end mattress sutures of silkworm gut) through the marks previously scratched on the skin (Fig 42) The following sutures (sim

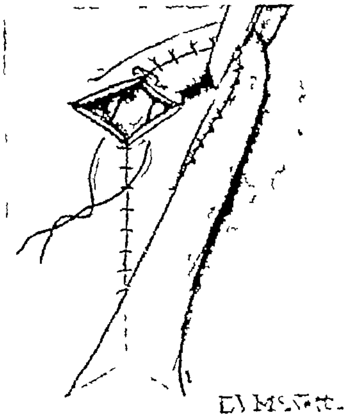


Fig. 43 Closure of triangular raw surface at end of tube flap and flap bed by insertion of mattress suture (Gillies)

ple interrupted silk sutures) close the remainder of the wound. If the flap bed cannot be closed by simple skin-sliding the flap bed should be skin-grafted.

Formation of Tube The next step consists in tubing the flap. The skin edges of the flap are inverted and sewn together with simple interrupted silk sutures. The first sutures approximate the marks previously scratched on the skin (Fig 42) The sutures are placed close to the skin margins They are left long to facilitate suturing the remainder of the flap edges There should be no tension along the suture line. If there is tension too much subcutaneous tissue has been included in

Case 106 *(continued)*, *d* Three weeks later, the flap was transplanted and fastened to the defect One week later, the flap was gradually severed from its pedicle This took two days The pedicle was then severed from the hand and discarded One week later, the flap was adjusted in place

e: Three years after the first operation No evidence of recurrence Full function of the shoulder joint

Case 106

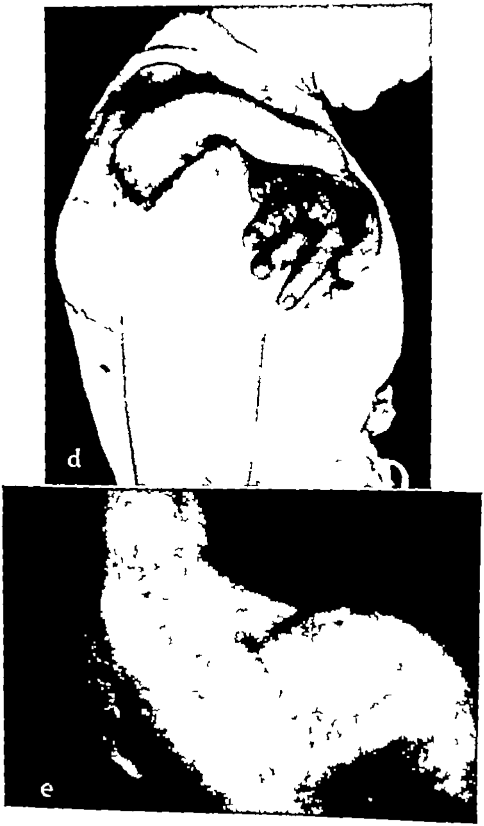
Case 107

Case 107, *a* Patient, aged forty-one, with atrophic traumatic scar formation over right elbow joint and upper half of lateral surface of forearm Scar was unstable and broke down Extent of the excision is outlined

b A large flap was developed from the adjacent chest region with a distal pedicle and transplanted in one stage The raw area of the flap bed was skin grafted

c The flap was gradually severed on the twelfth day, complete severance on the twenty-first day with adjustment of flap and pedicle

Case 106 (Continued)

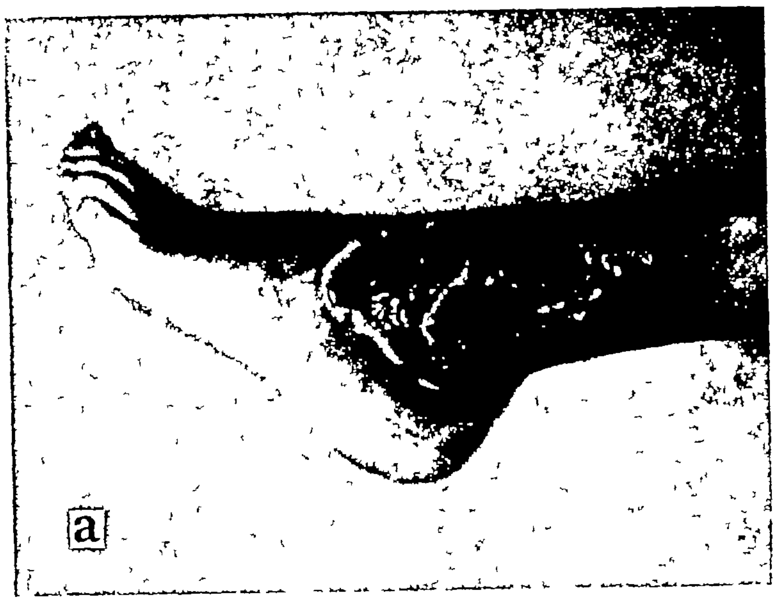


Case 108, *a* Ulceration and cicatricial changes over tibia after compound fracture of leg followed by osteomyelitis

b, c After removal of sequestrum and scar tissue, the surface defect was closed by relaxation incisions and mobilization of the skin between the incisions and defect Thus, double-pedicle flaps were formed which were shifted into the defect The secondary defects were skin-grafted

Case 107

Case 109



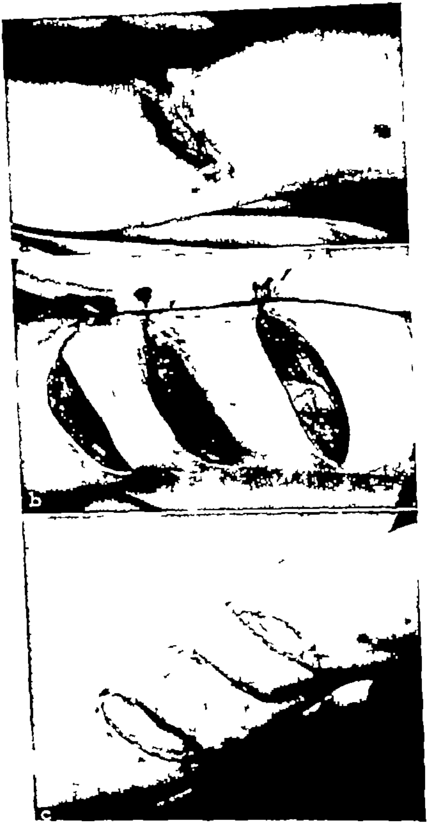
Case 109, *a* Patient, aged twenty-two, with extensive third degree burn of lateral surface of left ankle with exposure of fibula and fracture of left humerus after automobile accident

b A cross-leg flap was developed from the right thigh in stages First stage consisted of elevation of proximal half between two parallel incisions Two weeks later the upper and lower half was elevated between two parallel incisions Two weeks later the entire flap was elevated between the two pedicles, the proximal pedicle was incised from either side and laboratory clamp was applied to the middle portion of the pedicle The latter was gradually clamped Clamp was removed two weeks later

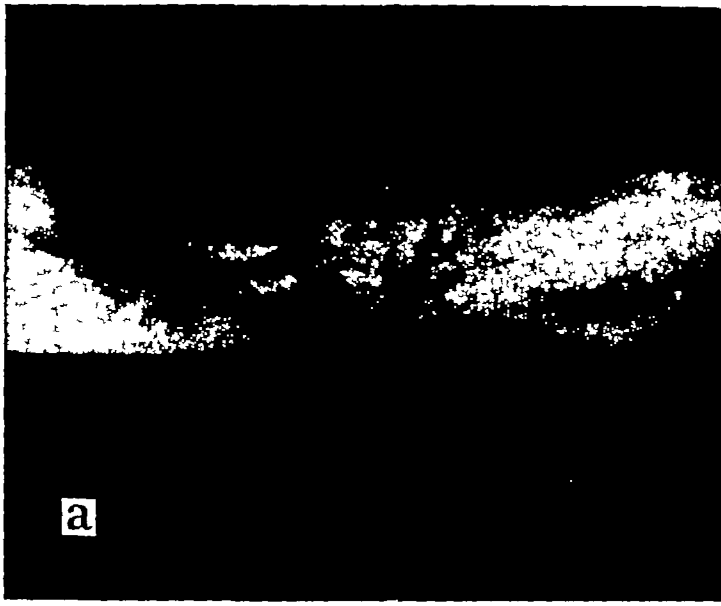
c Six weeks later the flap was elevated, flap bed covered with a split skin graft The terminal portion of the flap became cyanotic and for this reason it seemed advisable to return the flap It was laid upon the grafted flap bed and held in this position with a few sutures Two weeks later the flap was elevated again The ulcer of the left ankle was excised, the flap sutured to the raw area of ankle and both legs held in position with a plaster cast One week later the pedicle of the flap was incised from either side and an elastic clamp applied to remainder of the pedicle One week later the pedicle of the flap was severed completely, and the cast removed Another week later flap at left ankle and pedicle at right thigh were adjusted in place

d Five months after the accident

Case 108



Case 110



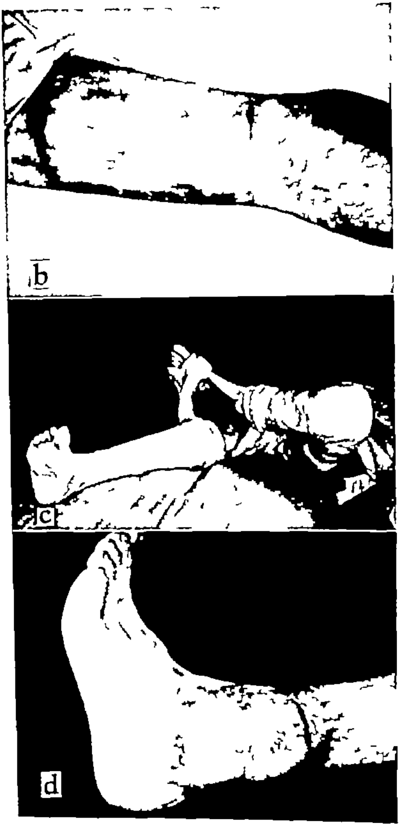
Case 110, *a* Patient, aged nineteen, suffered from a compound fracture and extensive loss of skin over the left leg from a motorcycle accident The fracture of the tibia was reduced and held stabilized with vitallium bone splint After the fracture had healed patient was referred for closure of surface defect

b A flap from the calf of the right leg was elevated between two parallel incisions Four weeks later the flap was elevated again and the distal pedicle was incised from either side, while a laboratory clamp was applied to the middle part of the pedicle The clamp was gradually tightened, and could be removed four days later Four weeks later the distal half of the flap was elevated and returned The tibial bone plates were removed Four weeks later the entire flap was elevated and returned The circulation of the flap appeared adequate The flap, however, became edematous and infiltrated during the following two weeks so that it was advisable to wait another six weeks until all edema had subsided in the flap before it was transplanted

c After removal of a large sequestrum the flap from the right calf was elevated and transplanted to cover the raw surface on the left leg The raw flap bed at the calf was covered with a skin graft Ten days later the pedicle of the flap was incised from either side and laboratory clamp was applied The pedicle was gradually crushed so that four days later the pedicle could be severed Five days later flap and pedicle of the flap were adjusted in place

d Subsequently several sequestra drained through the flap All wounds have healed since that time and the leg is stable

Case 109



the flap, and must be removed with scissors until the flap edges meet with ease

After the last sutures have been placed, one will notice a triangular raw surface at each end of the flap and likewise at each end of the donor area opposite the raw surfaces of the tube. Gillies closes these areas as demonstrated in Fig 43 To eliminate these small raw areas, Davis and

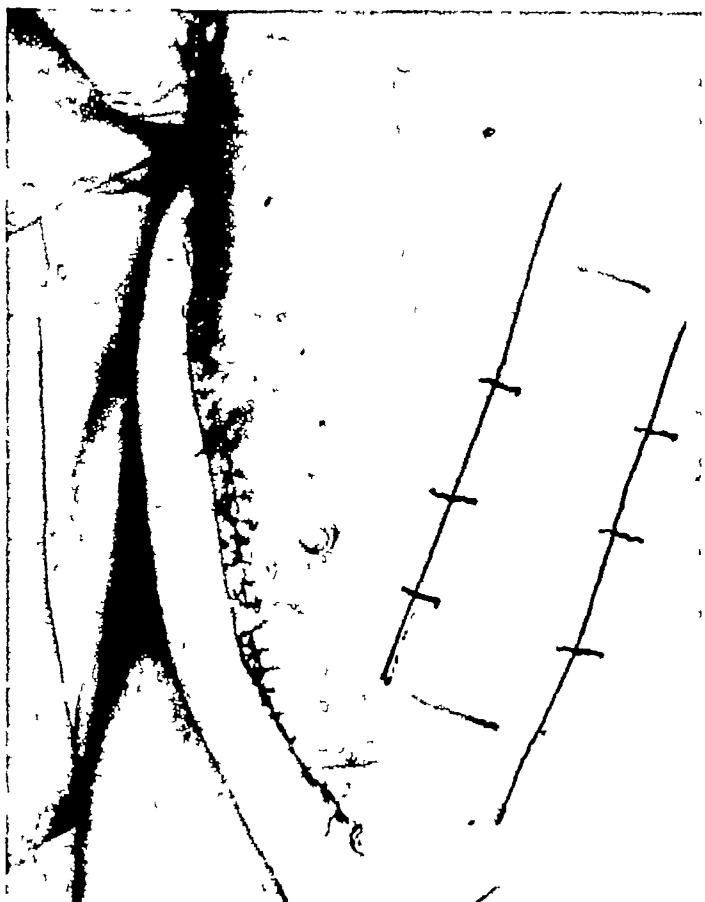
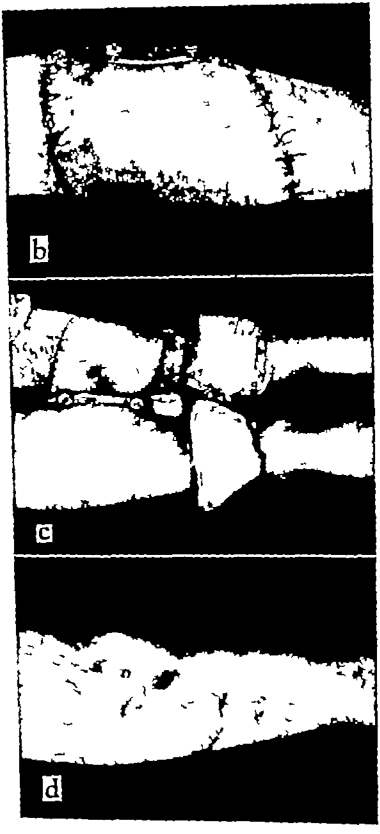


Fig 44 Demonstration of avoiding raw areas at end of tube flap and flap bed by staggering parallel incisions (Davis and Kitlowski) (compare with Fig 43) Tube flap on patient's right side had been outlined as depicted on his left side Ends of parallel incisions are so placed at each pedicle end of proposed flap that one of the lines extends somewhat beyond point where flap is to terminate (Case 106, p 990)

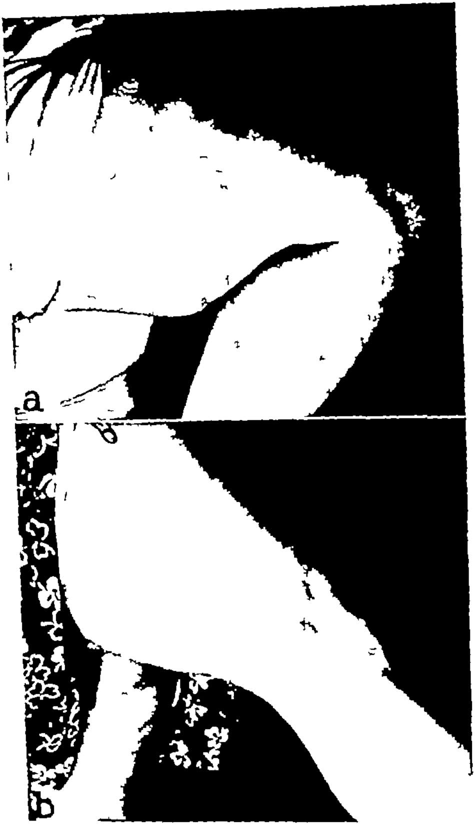
Kitlowski stagger the parallel incisions The ends of the parallel incisions, instead of being exactly opposite each other, are so placed that at one pedicle end of the proposed flap one of the lines extends from 3 to 4 cm ($1\frac{3}{16}$ to $1\frac{5}{8}$ inches) or more beyond the point where the flap is to terminate, and conversely at the other pedicle end (Fig 44)

Case 110



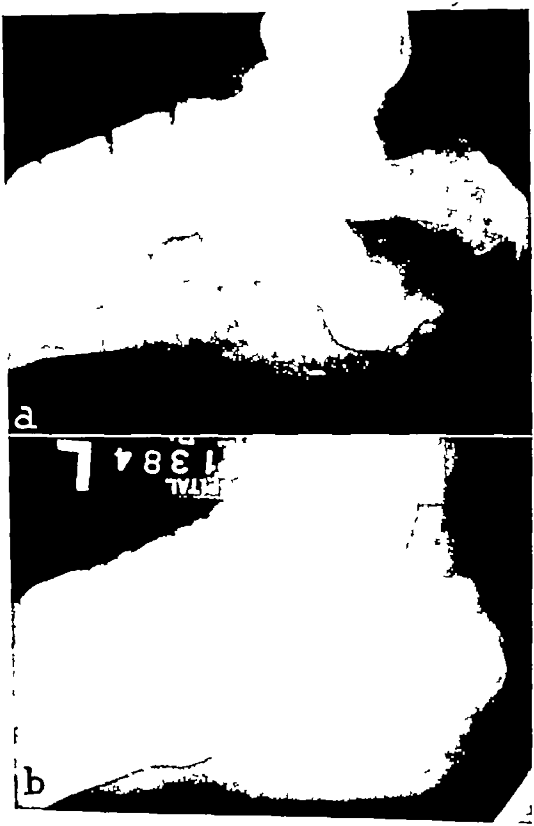
Case 113 Nonunion of the right patella with wide cleft after unsuccessful wiring. Patient referred to the author The patella was exposed from a U-shaped incision Both fragments were sclerotic, and had to be removed (p 579). The rent in the tendon was so wide that direct approximation of the tendon stumps was impossible A lengthening of the quadriceps tendon was performed, according to the method of Fig 324, p. 584 The lengthened proximal stump was sutured to the distal end The extremity was immobilized for six weeks in a plaster cast—the first three weeks in a long cast and the following three weeks in a short cast. After removal of the cast, physiotherapy was instituted Good functional result after six weeks

Case 113

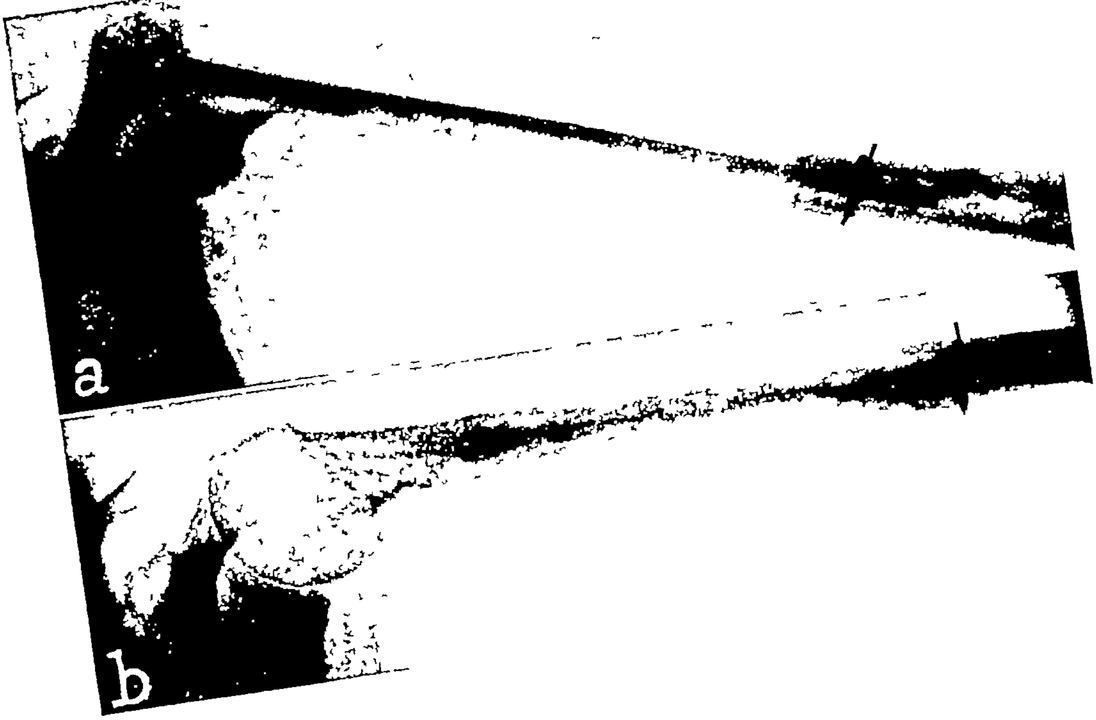


Case 114 Patient, aged twenty-six, was operated on for repair of a cicatricial hernia Two days later, he developed a postoperative psychosis He left his room through the window, climbed down three stories along a lightning rod, jumped over a fence, and in doing so split his calcaneus from contracture of the Achilles tendon Yet he was able to outdistance his pursuers for three blocks He recovered from the psychosis the following day Six days later, a hematoma at the site of the herniorrhaphy was drained The repair work itself had held The split of the calcaneus was repaired with a wire suture, according to the technic outlined on p 580 Immobilization of the extremity for six weeks Full functional recovery

Case 114



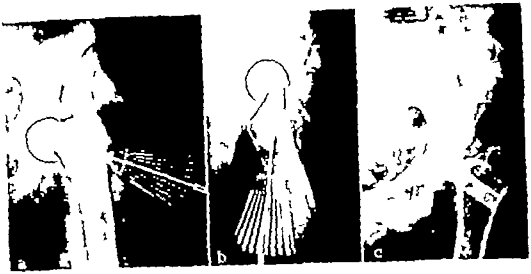
Case 115



Case 115, *a* Proximal two thirds of shaft of humerus removed for cystic degeneration Defect bridged with a periosteum-covered fibula graft (for technic, see p 636)

b Twenty weeks after operation (Case of E Lexer)

Case 116



Case 116 *a b* Patient aged sixty-eight with nonunion of neck of femur after unsuccessful nailing six months previously The cleft is narrow The head fragment had undergone atrophy hence appeared to be alive. A fibular bone graft was inserted according to the technic described on p 658 Immobilization in plaster cast for three months. Partial weight bearing after five months. Full weight-bearing after nine months.

c Nine months after operation Patient walks with a slight limp the shoe is elevated 1.2 cm (½ inch) No pain.

Case 117

Case 117, *a* Patient, aged fifty-four, with nonunion of neck of femur after insertion of two screws three months previously Case referred to author for bone-grafting Head fragment had undergone atrophy, hence appears to be alive

b, c Insertion of fibular graft, according to technic described on p 638 Immobilization in plaster cast for three months, partial weight-bearing after five months Full weight-bearing after ten months Result ten months after operation Patient walks without limp, no pain

Case 118

Case 118, *a* Patient, aged fifty-two, was struck by an automobile Admitted unconscious, with fractures of right clavicle, right radius, eighth rib, right fibula, and double fracture of right tibia He regained consciousness soon No treatment for fracture of clavicle, reduction and immobilization of fracture of radius, application of plaster cast to right leg All fractures healed with exception of the double fracture of the tibia The middle fragment became dense, while the proximal and distal fragments underwent atrophy These x-ray findings made it evident that the middle fragment was deprived of circulation and underwent aseptic necrosis A major bone-grafting operation did not appear advisable, owing to the impaired general condition of the patient Hence, a fibular transfer in two stages was planned, according to the technic described on p. 551.

b, c. First stage Fusion of upper tibiofibular joint with bone-pegging (note bone peg through head of fibula) *Second stage* (six weeks later) Osteotomy of lower part of the fibula and fusion of this part with the tibia This step was facilitated by an accidental fracture of the fibula during the operation Immobilization of the extremity in plaster cast for three months Marked swelling of the leg from poor circulation (arteriosclerotic changes) subsided gradually upon physiotherapy Patient on crutches

Eight months after the last operation, patient fell and fractured femur of the same side through the intertrochanteric line Insertion of Smith-Petersen nail, according to the Engel-May method (see p 638) with intertrochanteric attachment Seven days after the operation, patient fell out of the wheelchair upon the right leg All former fractures held Up and around on crutches thirteen days after the operation Walking without support ten months after the second operation and two months after the nailing operation

Case 117

Case 118

Case 119

Case 119, *a* Patient, aged twenty-one, sustained a fracture of the right fibula and double fracture of the right tibia in a motorcycle accident The fibular fracture healed, the double fracture of tibia had not healed seven months after the accident Note the density of the middle fragment as compared with the atrophy that the proximal and distal fragments have undergone Hence, from x-ray examination, it was evident that the middle fragment was dead

b The tibia was exposed from an anterior incision The middle fragment was removed subperiosteally, it then was halved, the posterior half was replanted The proximal and distal fragments were prepared for reception of a bone graft, that is, the anterior cortex was removed The fibula of the same side, covered with its periosteum, was removed through a separate incision It was laid upon the three fragments, and fastened with wires This roentgenogram was taken five months after the operation Patient discharged in a walking-brace

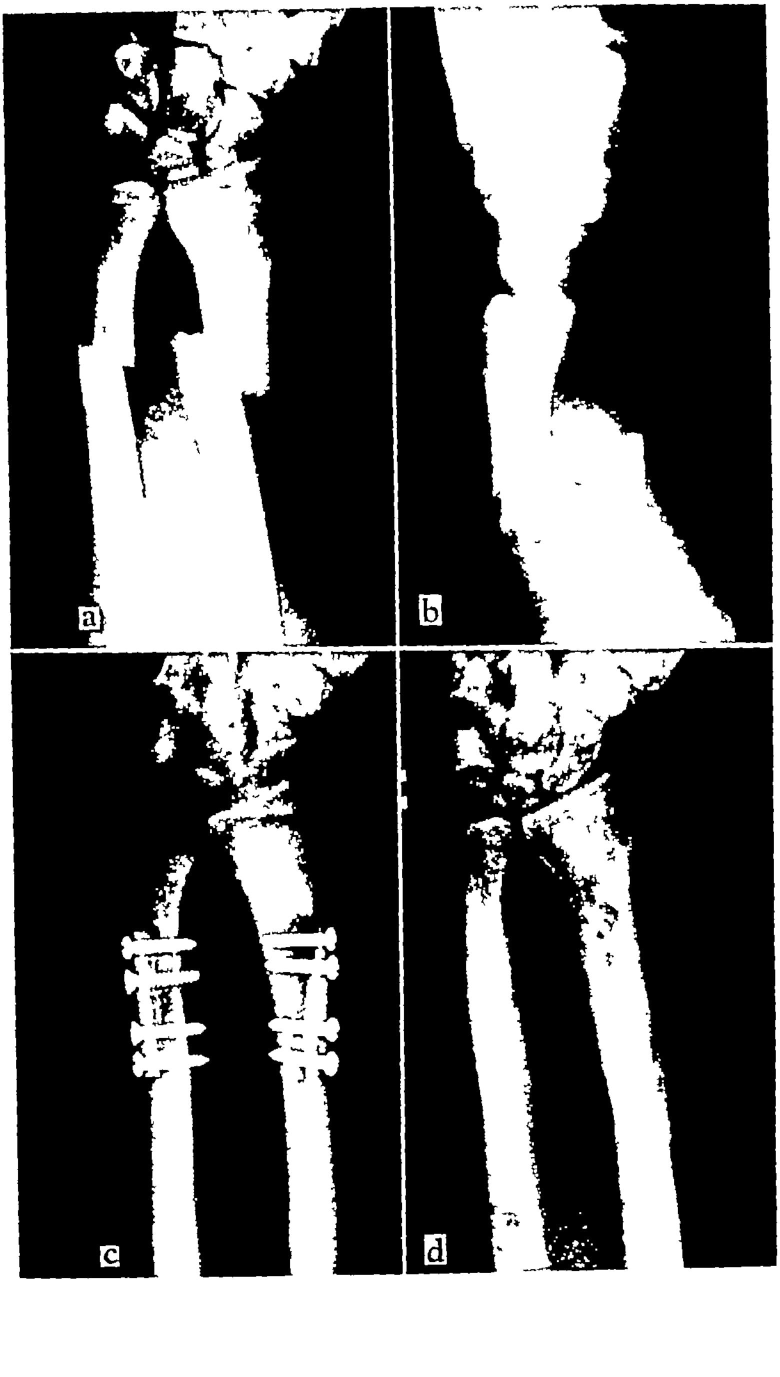
c Two years after the operation Patient walked without support No limp The wires had been removed one year after the operation in order not to delay regeneration

Dressing and Postoperative Treatment of Flap Several layers of bismuth tribromophenate (xeroform) gauze are placed beneath the tube on the suture line of the flap bed the ends of the gauze are cut longitudinally in half to be wrapped around the pedicles of the tube If the graft bed was skin-grafted, a proper pressure dressing must be applied beneath the tube. The dressing however should not be so thick as to

Fig. 45: Dressing of tube flap Long rolls of gauze, thicker and longer than the flap, are placed along each side of flap and fastened with adhesive strips. A dressing pad is then placed over entire area.

cause stretching of the overlying flap Long rolls of gauze (somewhat longer and thicker than the flap) are now placed along each side of the flap and held in place with adhesive strips (Fig 45) A dressing pad is placed over the whole area The flap should be inspected frequently for possible hematomas or edema which may interfere with the flap's cir

Case 121

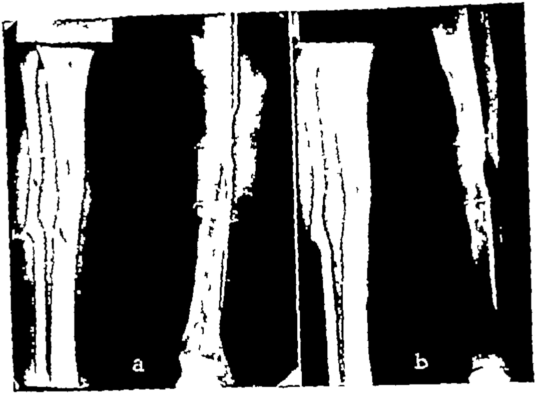


Case 121, *a*, *b* Fracture of radius and ulna with marked displacement Closed reduction failed

c After bone grafting Bone grafts were taken from the tibia

d The screws were removed six months after the operation This roentgenogram was taken two and one-half years after the accident

Case 120



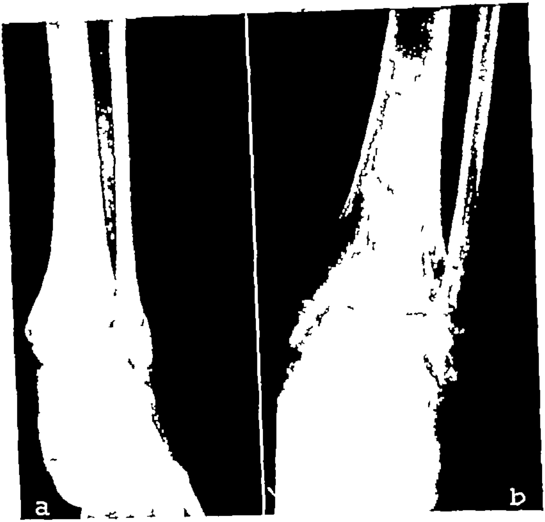
Case 120 *a* Patient, aged thirty two with nonunion of right tibia bridged with a periosteum-covered sliding graft from the proximal fragment (compare with Fig. 314 p 634)

b One year after operation

Case 123, *a, d*· Boy, aged sixteen, had fallen from a fence two years previously. Since the injury, the left leg had gradually become bowed The fall had injured and closed the median portion of the proximal epiphyseal cartilage plate of the tibia, while the lateral portion still functioned (see roentgenogram).

b, c, e An oblique osteotomy was performed at the site of the curve through the lateral and anterior cortex of the tibia in a plane parallel to that of the knee joint. Osteotomy of the fibula (for technic, see p 649) The deformity was corrected and a plaster cast applied from the toes to midthigh. The cast was changed after four weeks, sutures were removed, and another long cast was applied with a walking-iron incorporated The osteotomies were firmly united after six months No recurrence of the deformity.

Case 122



Case 122 *a* Girl aged sixteen with a fracture of lateral and median malleoli which had not healed four months after the accident

b Bone-pegging through median malleolus the bone peg was removed from tibia of same side (see p 618) Immobilization for three months Complete union

Case 124, *a, b*: Patient, aged fifty-two, while working as a brakeman was thrown from a box car, and sustained an intra-articular comminuted fracture of the proximal part of the right tibia The fragments were depressed, and laterally and posteriorly displaced Traction by means of a Kirschner wire through the heel, together with manual impaction of the fragments, did not improve the displacement Hence, an open reduction was performed two weeks later to achieve a proper articular plane Under considerable difficulties, the displaced and impacted fragments were mobilized and could be raised, but a satisfactory articular plane could not be obtained The crucial ligaments, as well as the collateral ligaments, were found torn No attempt was made to repair them The joint was closed and the extremity immobilized in a plaster cast

c, d After the fracture had healed—three months after the first admission—hemiarthroplasty was performed The joint was exposed from an anterior U-incision (Fig 361, p 669) The tibial articular surface, which was irregular and showed marked arthritic changes, was remodeled A fascia-fat-tissue graft, taken from the thigh of the same side, was placed upon the raw surface of the tibia After closure of the wound, immobilization and after-treatment were instituted as described on p. 673.

e, f Patient regained satisfactory function within the following six months He walked without pain, but the joint had some lateral instability, which prevented him from resuming his former job

Case 123

Case 125, *a* Female, aged twenty-three, with a tumor within the lateral half of the upper fourth of the right tibia There was no evidence of metastasis An amputation of the right lower extremity above the knee joint was planned in case the biopsy revealed a malignant tumor The amputation, however, was refused by the patient At the same time, a male, aged seventy, was in the hospital, with arteriosclerotic gangrene of the right foot, with partial blocking of the popliteal artery, necessitating an amputation above the right knee joint

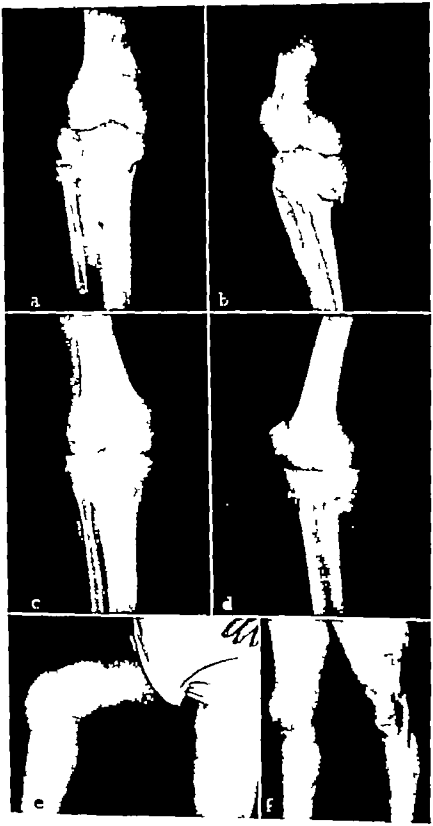
b A compromise operation was now planned for the first patient Permission for such an operation was given The operation was carried out in June, 1933 (operators, Lexer-May) The biopsy confirmed the diagnosis of sarcoma From a Y-shaped incision in front of and below the right knee, the joint was opened after separation of the tibial tubercle and lifting it upward, together with the skin flap and quadriceps tendon The tumor was now exposed Then followed the separation of the crucial ligaments and of the median and lateral ligaments at their insertion at the tibia The head of the fibula and the upper third of the tibia were now resected The tibial resection was staggering By the second operating team, the corresponding part of the tibia of the male patient had been resected in a similar way, and was now transplanted into the girl's leg and fastened there with two wire loops The lateral and median ligaments were attached to the tibial transplant as well as possible The quadriceps tendon, together with the tubercle of the tibia, was fastened to the transplant with a wire suture The wound was closed in layers, application of plaster cast, immobilization (with a brace) for 21 months Then pain developed

c Roentgenograms revealed a slight depression of the median knee-joint surface, where most of the pain was concentrated Since there was the possibility of a pathologic fracture at this site, the patient was operated upon again, but no evidence of recurrence was found The soft tissues were found to be in intimate connection with the graft, no fracture, just below the insertion of the quadriceps tendon, a piece of the cortex was removed in order to permit inspection of the inside of the graft Necrotic fat tissue and sandlike sequestra were emptied from the superficial spongy layers, while deeper inside profuse bleeding was encountered The upper wire was now removed and the wound closed in layers After healing of the incision, the patient had to use the brace again for walking At the end of 1937, the patient was allowed to discard the brace again She could walk without any support.

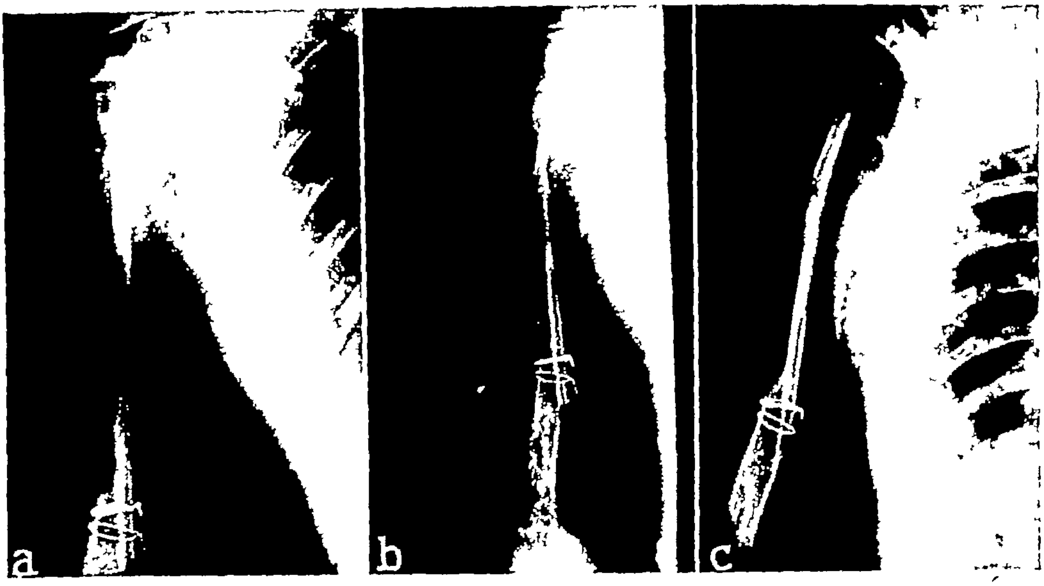
d A roentgenogram, five and one half years after the operation, revealed no evidence of recurrence, but roughening of the joint surface

e, f In spite of these changes and a moderate genu-varum deformity, the patient walked without any pain or limp In January, 1939, she felt a dull pain in her epigastrium Before long she became jaundiced The family doctor advised against an operation The patient died, February 19, 1939, five and three quarter years after the operation An autopsy was not performed

Case 124



Case 126

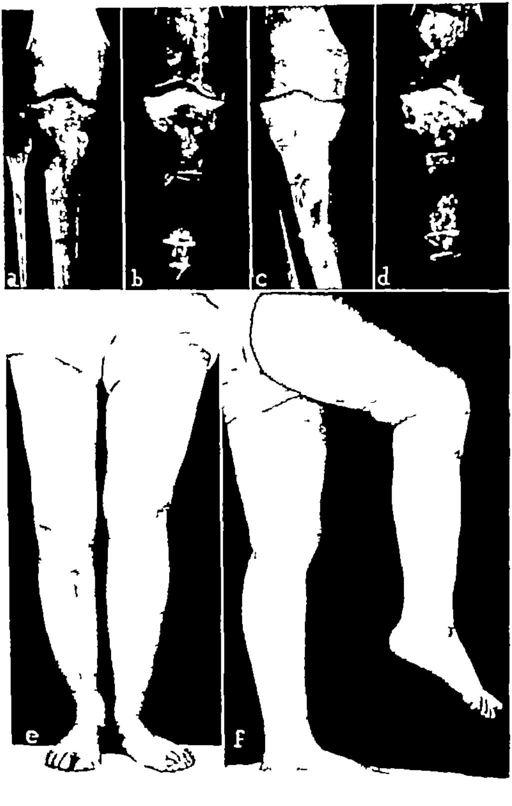


Case 126, *a* Patient, aged seventeen, had a low-grade sarcoma in the proximal third of the humerus, verified by biopsy (frozen section) The proximal two thirds of the humerus was removed, and the defect was replaced with a fibular graft (operators, Lexer-May) (for technic, see p 674) The proximal third of the fibula was removed by the second operating team The head of the fibula was placed in the glenoid of the scapula, the distal end fastened to the distal stump of the humerus Immobilization in a chest-arm cast The cast was removed after five months

b One month later, the graft fractured Reapplication of the cast

c Three months later, the fracture had healed, and graft and humerus had fused The patient died seven months later from lung metastases

Case 125

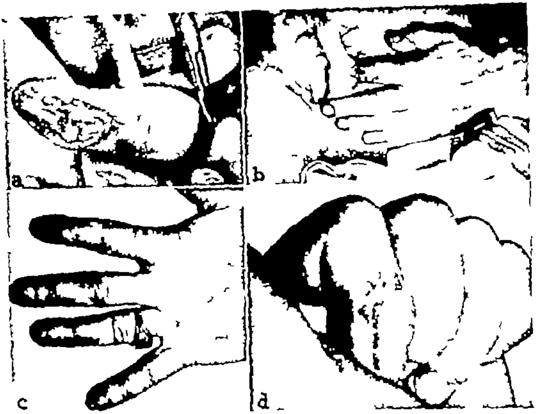


culation If this is the case, the hematoma should be emptied or the edema relieved by removing some of the sutures Massage and application of local heat may be of help in decreasing the edema The sutures of the flap are usually removed seven or eight days after the operation, and also the simple sutures of the donor area, the on-end mattress sutures of the donor area should remain longer in place

Fig 46 Separation of proximal pedicle of tube flap by application and gradual tightening of laboratory clamp

Separation of Pedicle: The next step consists of separating the one pedicle which is to become the peripheral end of the flap. Although German, Finesilver, and Davis, in an experimental study, found the establishment of an adequate blood supply from a single pedicle within seven days, the vascular pattern in a tube flap, however, becomes established much later, according to Braithwaite et al Hence, the separation of the

Case 127



Case 127 *a* Grinding injury of dorsum of left index finger Note loss of dorsal half of bone of terminal phalanx and exposure of terminal joint (Patient is left handed.)

b After excision of the wound, a pocket flap from opposite side of the abdomen was transferred immediately The donor area was closed by skin-sliding The arm was immobilized in a plaster cast (for technic of application of cast see p. 71 and Fig 56 p 72)

c d Severance of the proximal pedicle after seven days of the distal pedicle after ten days. Adjustment of the free ends of the flap and defect edges two weeks later

Case 128, *a* Traumatic defect of tip of fourth finger Exposure of bone Conservative treatment for four weeks elsewhere was unsuccessful

b. A flap with a proximal pedicle was raised from the palm and sutured to the defect.

c Immobilization of finger with adhesive strips one or two running over dorsum of hand and finger to palm, one or two, transversely over finger and just proximal to flap

d, e The pedicle of the flap was narrowed on the eighth postoperative day, and severed on the eleventh day, followed by adjustment and approximation o the free edge of the flap and defect edge on the fourteenth day.

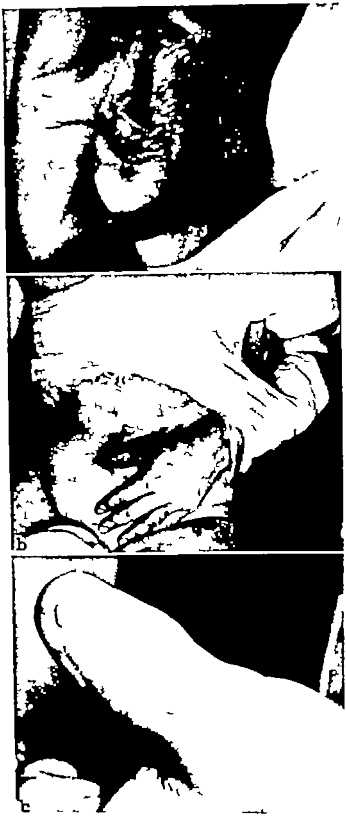
Case 128

Case 129, *a* Traumatic defect of dorsum of terminal phalanx of left thumb Note loss of dorsal half of bone of terminal phalanx and exposure of terminal interphalangeal joint

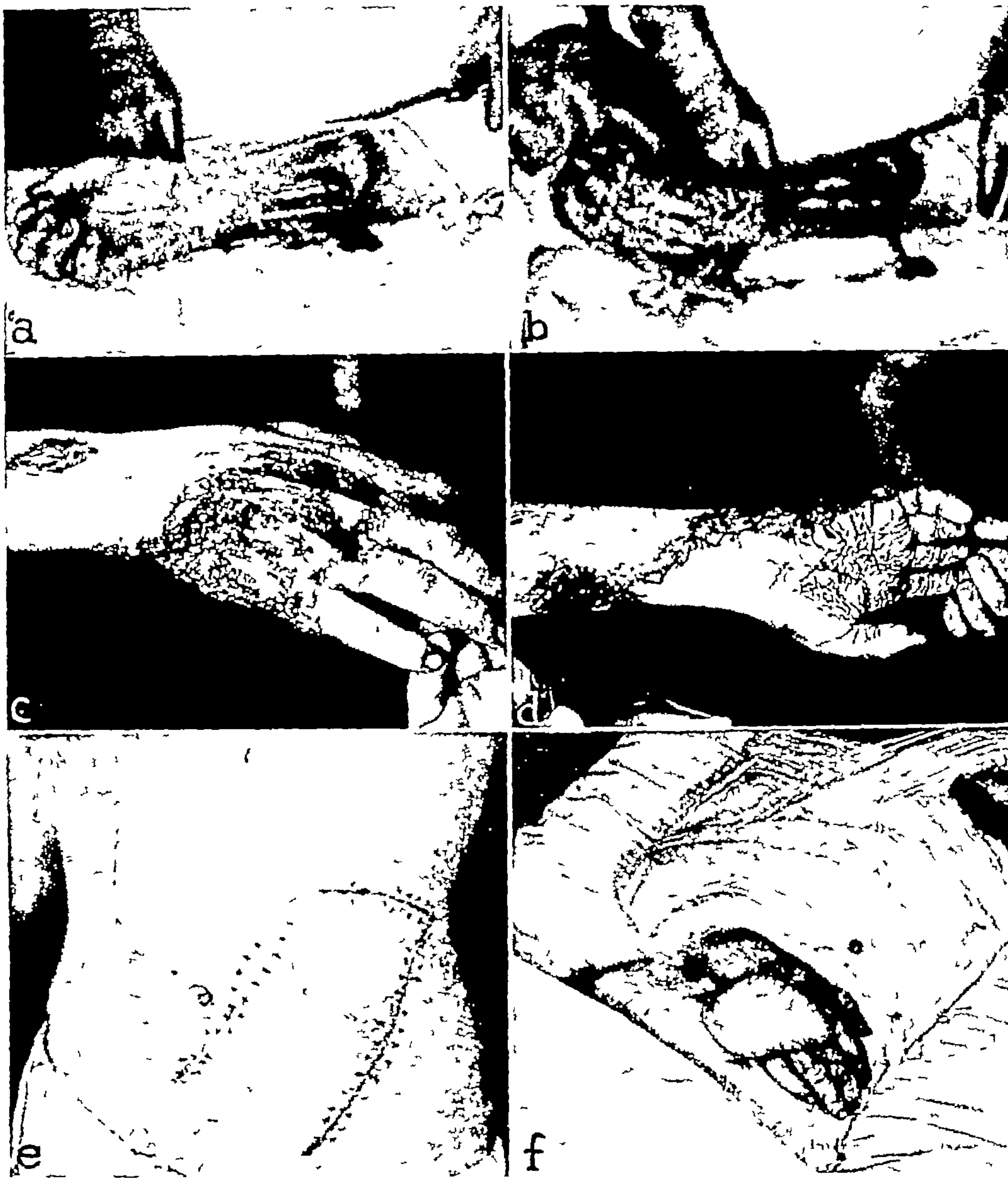
b After excision of the wound, immediate transfer of a single-pedicle flap from left upper abdominal wall The donor area was closed by skin-sliding Immobilization in a plaster cast (for technic of application of cast, see p. 71)

c Clamping of the pedicle was begun on the ninth postoperative day (see p 71) The flap was severed on the twelfth day Eleven days later, the free end of the flap was undercut and sutured to the defect edge

Case 129



Case 130



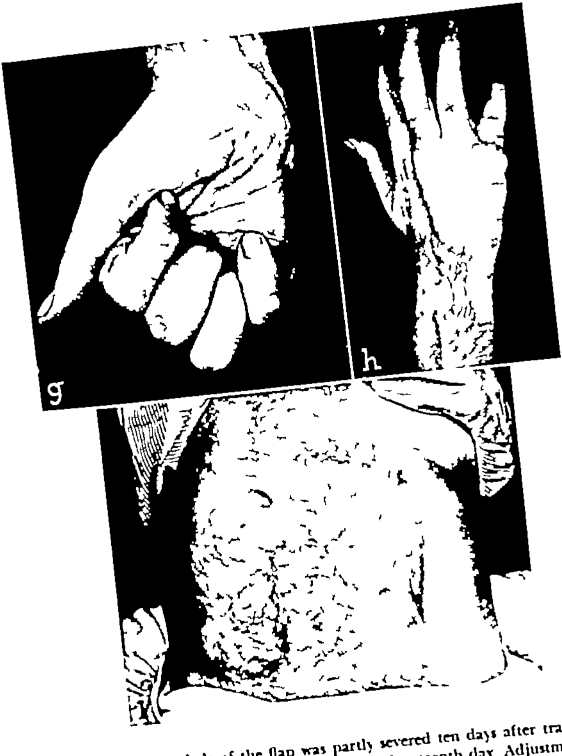
Case 130, *a, b, c* Extensive loss of surface tissue on volar and dorsal side of forearm and hand Exposure of tendons, loss of extensor tendon of fifth finger

d After excision of the wound, the defect was immediately closed at the forearm by wide undermining of the wound edges and skin-sliding. A relaxation incision on the dorsum of the forearm facilitated skin-sliding

e An open abdominal flap was raised from the opposite side of the abdomen in the same operation The flap was raised between two parallel incisions After one week, the proximal pedicle was incised and sutured

f The flap was raised on the fourteenth postoperative day, it did not change color. The flap bed was skin-grafted The flap was transferred to the right hand and accurately sutured in place Immobilization of the arm in a plaster cast

Case 130



g h The pedicle of the flap was partly severed ten days after transfer of the flap and it was entirely separated on the fourteenth day Adjustment and approximation of the free edge of flap and defect were performed two weeks later

i Donor area which had been skin-grafted as soon as the flap was raised.

Case 131

Case 131

Case 131 *a* Patient aged twenty-six years sustained severe crush and burn injury of left hand and forearm after arm was caught in a hot press. There was a fracture in the lower third of ulna and a hematoma and contusion of the median nerve. Emergency treatment consisted of decompression of the median nerve. Fifteen days after the injury the burn eschar was excised

b Six days later application of skin graft to one of the superficial surface defects of the dorsum of the wrist. An abdominal flap was elevated for closure of the other surface defects but the flap had to be returned, since the peripheral end became bluish discolored. One week later three narrow pocket flaps were formed at the abdomen for coverage of the surface defects over the knuckles of the interphalangeal joints of third fourth and fifth fingers. Abdominal flap was elevated again. The flap bed was skin grafted and flap transplanted to the wrist Seven days later the base of the main flap was incised on each side and a laboratory clamp was placed to the middle part. The bases of the finger flaps between two fingers were severed and a small laboratory clamp was applied to the lateral pedicles All clamps were gradually tightened. Six days later all pedicles were severed. Twenty days later flaps and pedicles were adjusted in place. At the third and fifth fingers the adjustment consisted of excision of a wedge shaped piece of tissue at each side of the flap and suturing the edges of the flap to the wound edges of the fingers. At the fourth finger however no adjustment of flap edges was made since they were too short.

c One year later all flaps were defatted in a two-stage operation. The median nerve in the meantime had regained full function

Case 132

Case 132, *a* Extensive wringer injury of distal half of dorsum of left hand, including a major part of the dorsum of the second to fifth fingers After the necrotic skin had sloughed off, all tendons were found to be intact Tendons, however, as well as joint capsules of the first interphalangeal joints, were exposed Actually, the joint capsules of the first interphalangeal joints of the third and fourth fingers were necrotic so that the joint surfaces were exposed Owing to the exposure of all these structures, skin-grafting had to be abandoned in favor of flap transplantation

b A large pocket flap was formed on the left side of the abdomen, into which the fingers were fitted, as into a glove. Seven days after the operation, the proximal pedicle—that is, the pedicle running along the radial surface of the index finger—was severed The flap edges were sutured to the wound edges of the index finger Twelve days later, all pedicles were severed, with the exception of the one which ran along the ulnar surface of the fifth finger Two days later, the last pedicle was severed Four weeks later, the skin bridges between the fingers were severed down to the webs of the fingers, and each flap was attached to the respective wound edge of the fingers

c, d Functional result six weeks after the final operation Patient ha returned to former duties

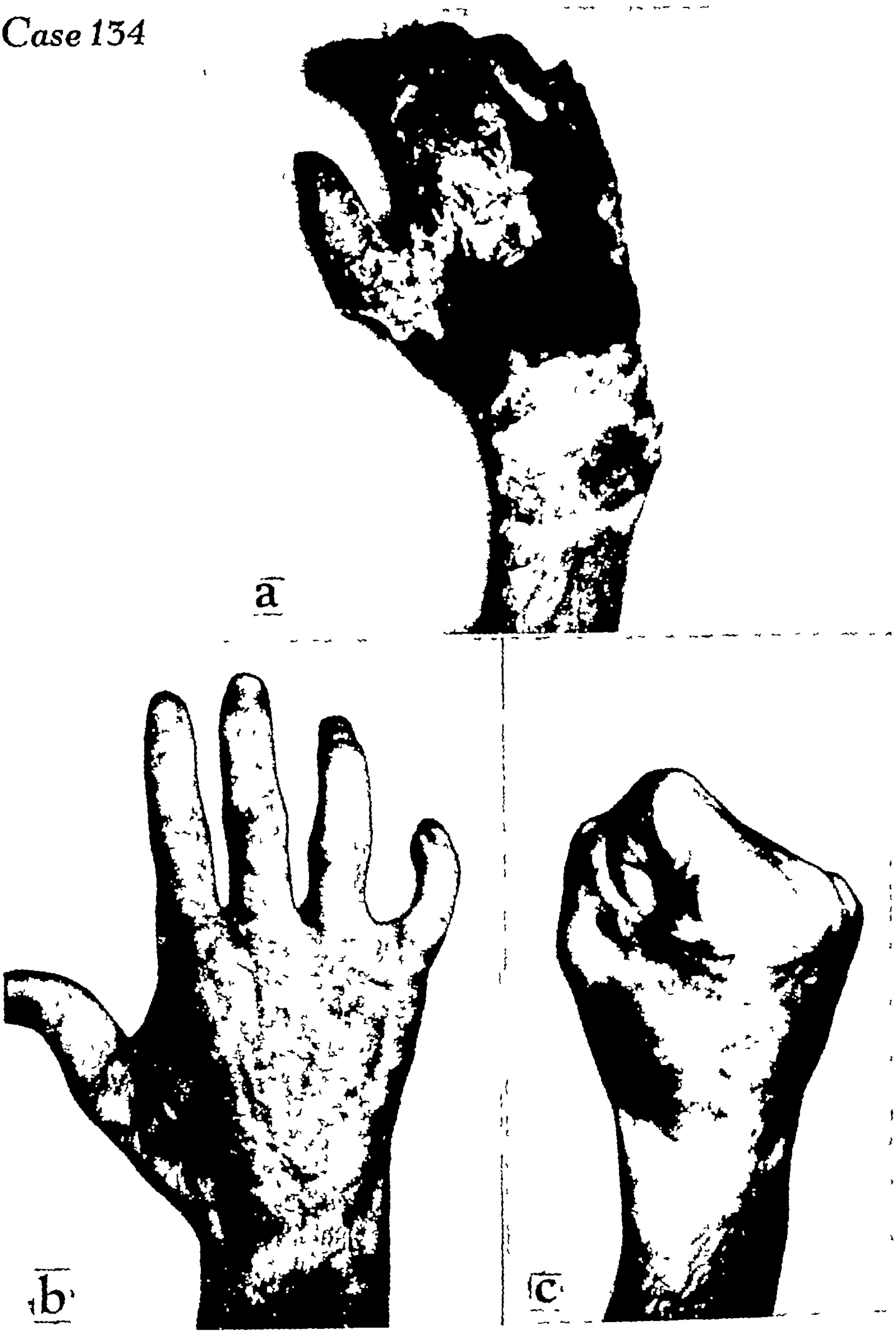
pedicle as a rule should not be performed earlier than three weeks after the operation In very long flaps several months may be required before the separation The blood supply is gradually interrupted by application and gradual tightening of an ordinary laboratory clamp on the pedicle (May) (Fig 46) Before applying the clamp it is advisable to incise the skin at this particular site to prevent slipping of the clamp and to lessen the pain and also to inject a few cubic centimeters of procaine before each tightening After each tightening, the circulation is tested as previously described (p 75) Other clinical as well as chemical tests are available (Conway et al and others) The author, however has found the clamp method both simple and versatile Finally, the pedicle is severed but the flap should not be transplanted immediately One should wait until all edema has subsided or until the circulation in the flap has become more adjusted to reversed conditions.

Transfer of Tube Flap The flap is now ready for transfer This can be done directly or indirectly

Direct Transfer Direct transfer is possible if the flap (1) by its own length can be transferred to the defect (Case 11 p 860), or (2) if the flap and defect can be approximated by favorable posture (Case 39 p 900) The peripheral end of the flap is then opened along the seam that is along the scar where the skin edges were brought together The cicatricial wound edges including the scar running to the center of the tube may need excision The flap is then unfolded If the flap is too thick, some of the fat tissue must be removed care should be taken not to injure the longitudinal branches of the larger vessels. The flap is now shaped and fitted into the defect. With a few cotton sutures, the base of the flap is anchored to the base of the host tissue The edges of flap and defect are then approximated with subcutaneous cotton sutures and silk sutures for the skin. There should be no kinking or tension of the flap Proper fixation with adhesive strips or plaster of paris may be necessary to avoid tension (Case 39 p 900)

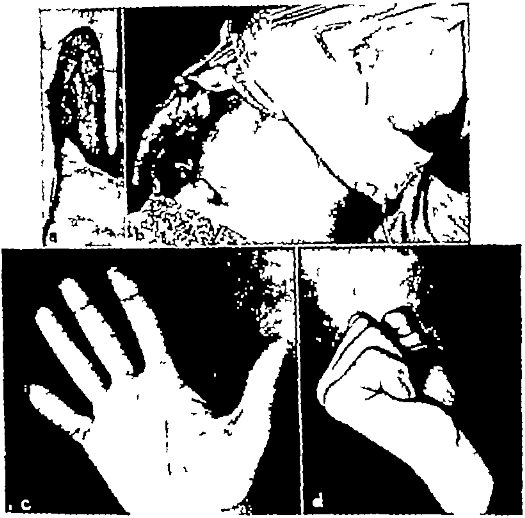
Indirect Transfer Indirect transfer becomes necessary if, owing to long distance between donor and host areas a direct transfer of the flap is not possible The flap is transferred by an intermediate carrier usually the wrist or forearm (Cases 11 106 pp 860 990) To avoid too much scarring at the arm a trap-door like flap is formed which is attached to the tube pedicle (Fig 47) After establishment of an adequate circulation between intermediate carrier and flap the other pedicle is severed and the flap transported by way of the arm to the defect. Another way of successive migration is by caterpillaring or waltzing· One pedicle is severed and attached to an area near the other pedicle or it is swung around

Case 134



Case 134, *a* Extensive third degree burn treated locally with pressure ings Condition twelve days after accident On the eighteenth day the necrot skin was excised and followed by application of saline solution dressings O the twenty-fourth day all raw surfaces were covered with split skin grafts *b, c* Result one year after the operation

Case 135

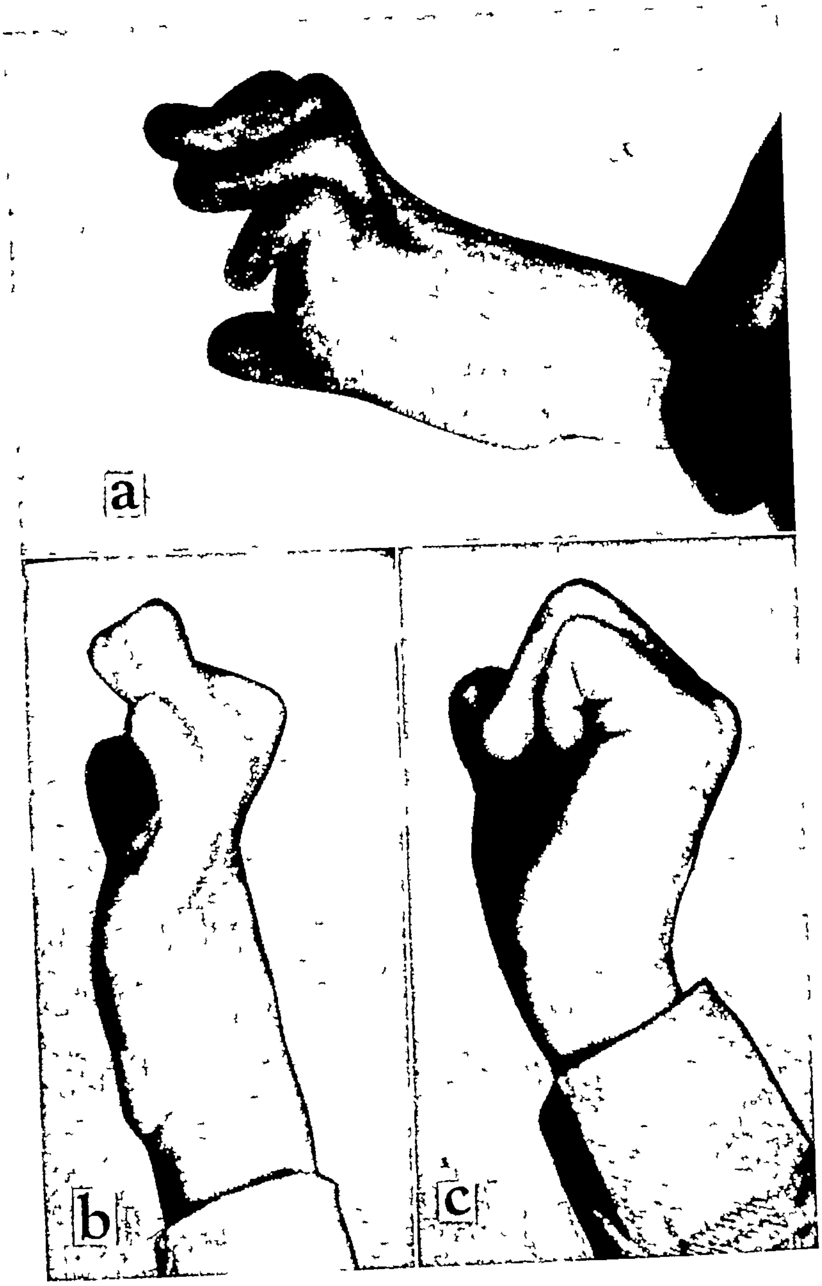


Case 135 *a* Patient, aged twenty nine admitted with extensive laceration of the volar surface and part of the ulnar surface of the right fifth finger Tendons were exposed as well as all vessels and nerves on the volar side In some parts, the tendon sheaths were missing

b A single-pedicle flap was prepared at the right side of the abdomen with a proximal pedicle The flap was then transplanted to the raw surface of the finger and the arm was immobilized in a plaster cast. The raw surface of the flap bed could be closed by skin-sliding Eight days later partial separation of the flap was performed with application of laboratory clamp, according to the method described on p 71 Three days later separation of the pedicle. Removal of the cast, one week later and adjustment of flap and pedicle.

c d Functional result one month after operation

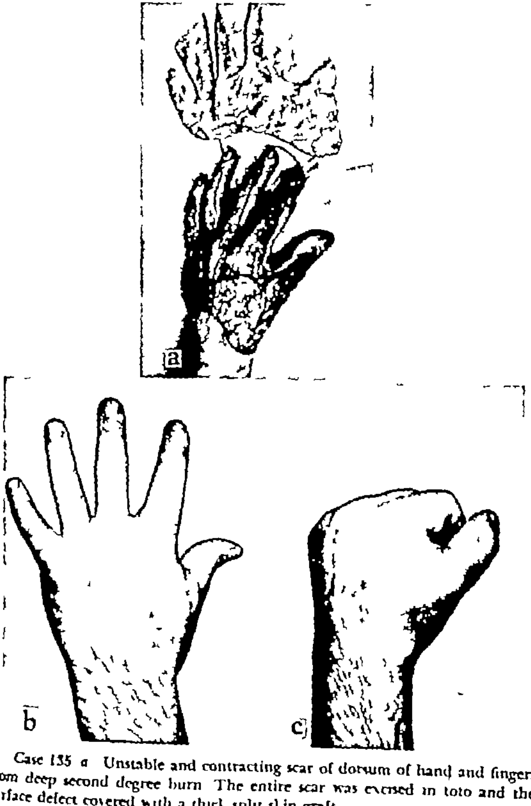
Case 136



Case 136, *a* Patient, aged five, had caught hand in a mangle Skin graft had been applied but apparently did not take Patient was referred three years later for repair of marked claw deformity of hand

b, c All the contracting scar tissue was excised The collateral ligaments of the metacarpophalangeal joints were severed, the contractures reduced as much as possible and the raw surface covered with thick split skin graft Five years after operation

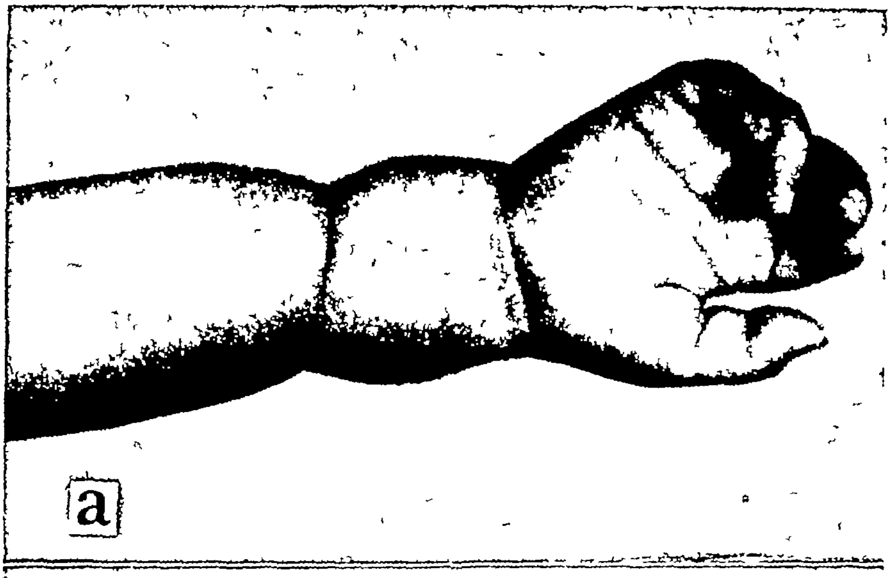
Case 135

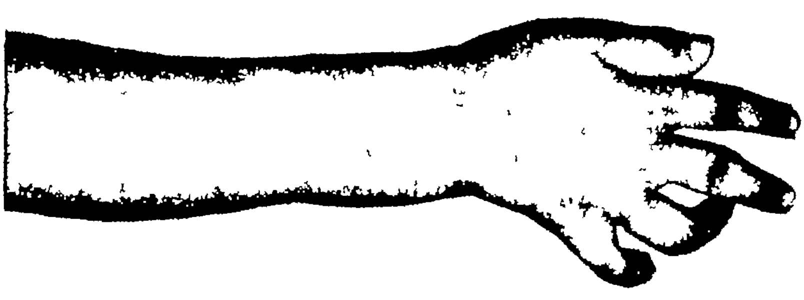


Case 135 *a* Unstable and contracting scar of dorsum of hand and fingers from deep second degree burn The entire scar was excised in toto and the surface defect covered with a thick split skin graft.

b c Five months after operation

Case 138

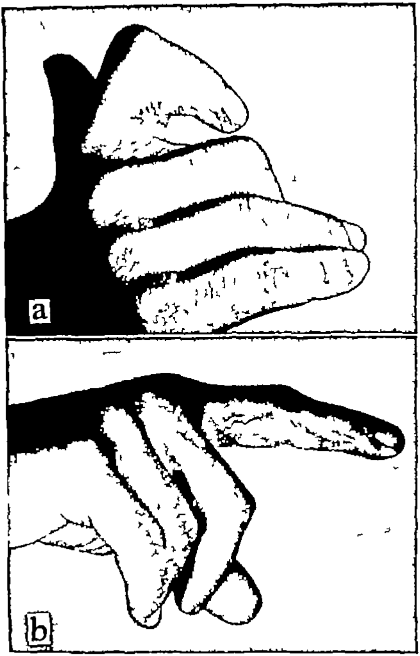

a


b

Case 138, *a* Girl, aged two, with congenital constricting bands of right forearm

b Constricting bands were overcome in a two-stage operation consisting of multiple Z-plasties

Case 137



Case 137 *a* Patient was treated in early youth for syndactylism of second and third finger No skin grafts were employed. Local flaps were utilized for closure of the raw surfaces. A contracture developed in the index finger web between index and third finger obliterated

b After release of contracture and closure of the raw surface with a thick split skin graft.

Case 140 Patient, aged forty, received fourth-degree burns over the dorsum of the left hand at the level of the second and third metacarpal bones Treated elsewhere When first seen by the author, the patient had a thick, unstable scar over the dorsum of the hand, with loss of the extensor tendons of the second and third fingers

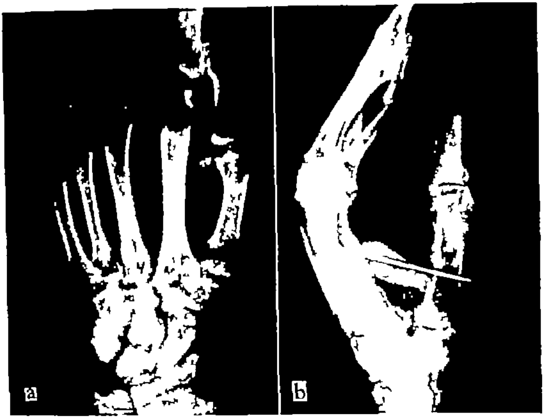
a The distal stumps of the tendons were adherent to the scar, preventing full flexion of the second and third fingers

b Abdominal flap was mobilized from the left side first, between two pedicles The distal pedicle was partly severed and a laboratory clamp applied to it (see Fig 37, p 74) During the following week, the distal pedicle was crushed gradually by tightening the clamp Three weeks later, the abdominal flap was mobilized The peripheral part of the flap became cyanotic, hence, flap was returned to its original site Six weeks later, the scar at the dorsum of the hand was excised. The abdominal flap was elevated, the flap bed skin-grafted, and the flap transferred to the dorsum of the hand Plaster cast applied One week later, the pedicle of the flap was partly incised and a laboratory clamp applied Six days later, the flap was severed from its pedicle

c Three days later, the flap and pedicle were adjusted in place Note the inability of patient to extend the second and third fingers Two months later, the defects of the extensor tendons were bridged by transplantation of a tendon graft, from the long extensor tendon of the fourth toe, to the second finger and by reconstructing the junctura tendinum between the third and fourth fingers through utilization of a tendon graft from the proximal tendon stump of the third finger Immobilization in extension for three weeks followed

d, e Patient regained almost full function of the second and third fingers A recent examination revealed full return of function

Case 139



Case 139 *a* Patient aged twenty-three, received severe crush injury of the right arm and hand with extensive lacerations. There was much destruction of the muscles and other soft tissues in the thenar region and between first and second metacarpal bones The injury resulted in obliteration of the web between the thumb and index finger and rigid adduction contracture of the thumb The contracture was of such degree that the thumb was in the way of the index finger when the index finger was flexed

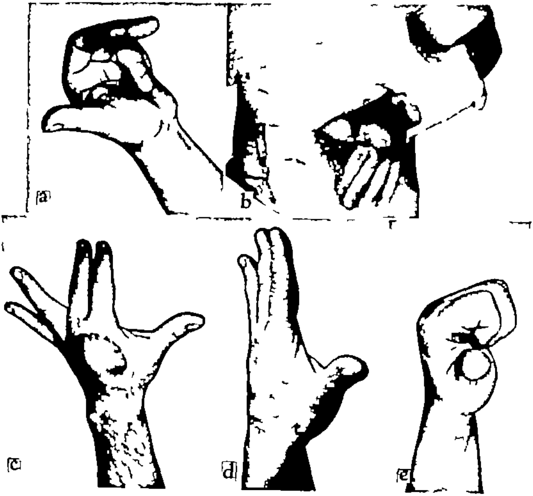
b Operation consisted of removal of massive contracting scar tissue between the first and second metacarpal bones, lengthening of the web with a Z plasty to counteract recontracture a bone graft taken from the crest of the ilium was placed between the first two metacarpal bones with the thumb in abduction and opposition. A Kirschner wire was drilled through the meta carpals and bone graft for stabilization. No additional immobilization This picture was taken seven months after operation.

Case 141, *a* Patient, aged forty-five, with Dupuytren's contracture of left hand of fifteen years' standing The contracture involved mostly the third, fourth, and fifth fingers There was, however, evidence of palmar nodules and contracting bands over the thenar region and the second finger

b The contracture was repaired, according to the method of Fig 370, p 699 The hand remained immobilized for two weeks Active motility in handbath was then permitted, but splint was reapplied for another week The photograph depicts the condition three weeks after the operation Thick split graft took completely.

c, d The patient regained full motility of her hand within eight weeks after the operation

Case 140



toward the defect and implanted, subsequently, the other pedicle is severed and transferred in the same manner until the defect is reached It is obvious that caterpillaring or waltzing is possible only if the flap is long enough to avoid torsion

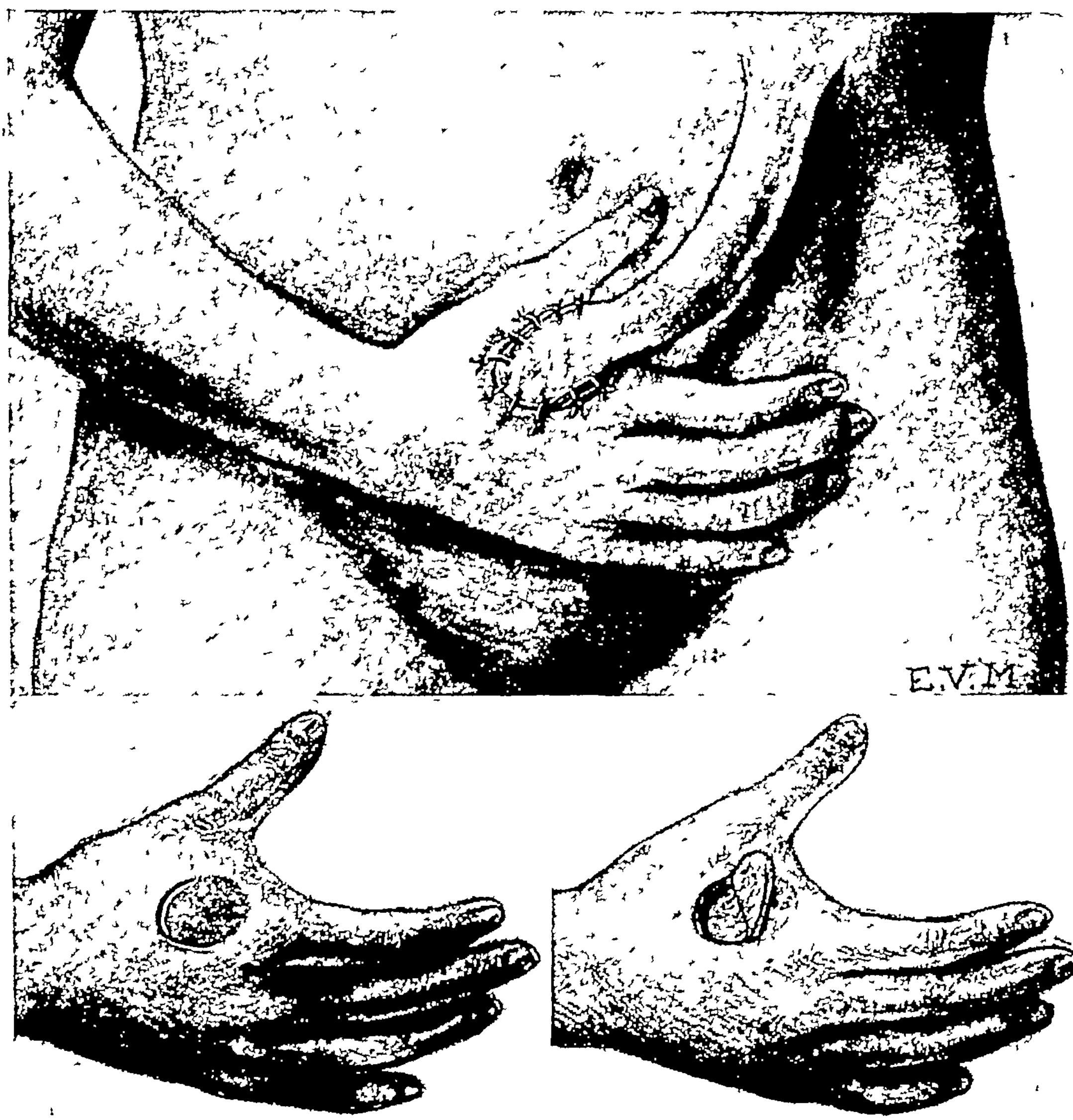
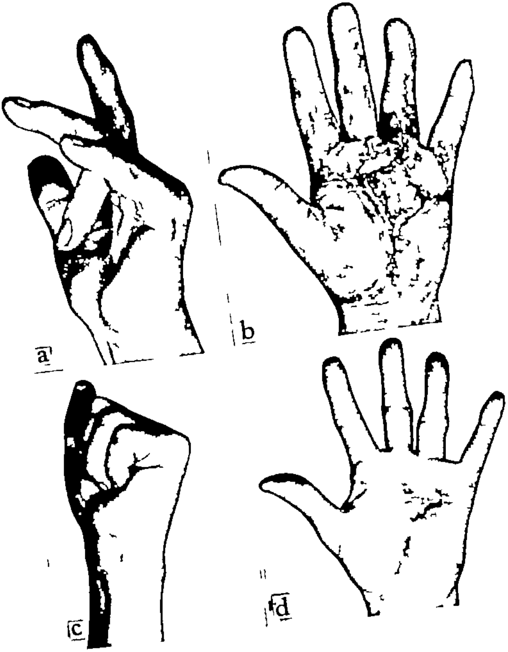


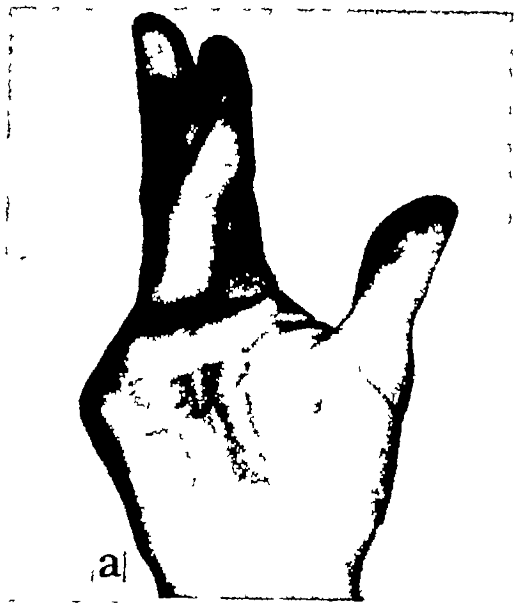
Fig 47 Successive migration of tube flap by using hand as intermediate carrier End of pedicle is made oblique Oblique raw area is pressed upon proposed area of fixation, outlining an oval imprint *(lower row, left)* One half of oval imprint is incised and raised, forming trap-door-like flap *(lower row, right)* Raw area thus created on hand corresponds in size to that of pedicle. Pedicle is sutured to trap-door flap and its base Later, when flap is severed, trap-door flap is reflected to its original site

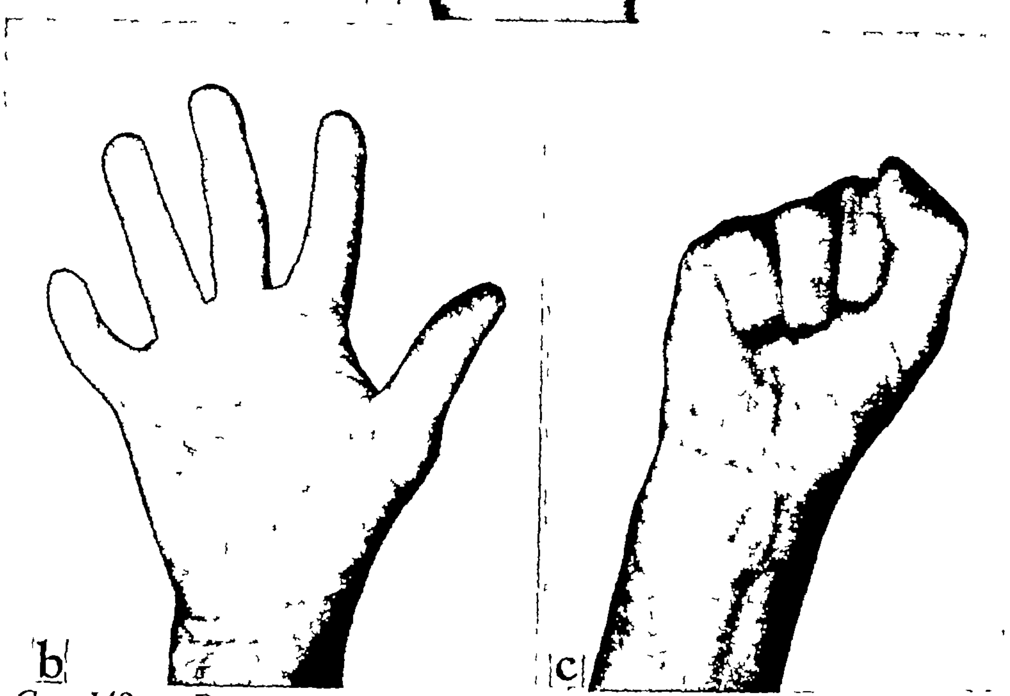
Separation and Adjustment of Flap Unless the flap, together with its pedicle, is to be used for transplantation, the flap must be separated from its pedicle Between seven and twenty-one days, depending upon the extent of surface attachment of flap and host area, the flap is grad-

Case 141



Case 142

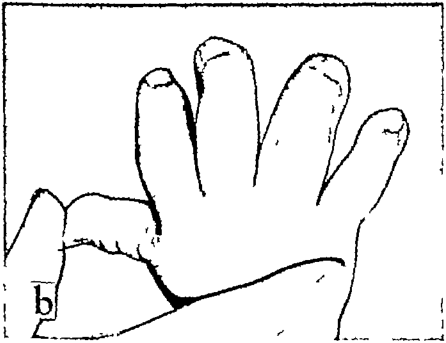




Case 142, *a* Patient, aged fifty-eight, received a Colles fracture of the right wrist Soon thereafter he noticed a gradual increasing contracture of the third, fourth and fifth fingers of right hand

b, c A typical Dupuytren's contracture developed which was operated on by excision of the entire palmar fascia and of the nodulous skin in the palm in the region of the fourth and fifth finger Defect was replaced with a thick split skin graft Two weeks after the operation the graft had taken well Immobilization was continued until the twenty-first day An Ace bandage was applied to prevent swelling and he was urged to do active motion exercises and daily hand baths One week later the bandage was left off temporarily but swelling of the knuckles and the dorsum of the hand occurred, the bandage was reapplied Four weeks later much function of the hand was regained and the bandage could be left off No swelling

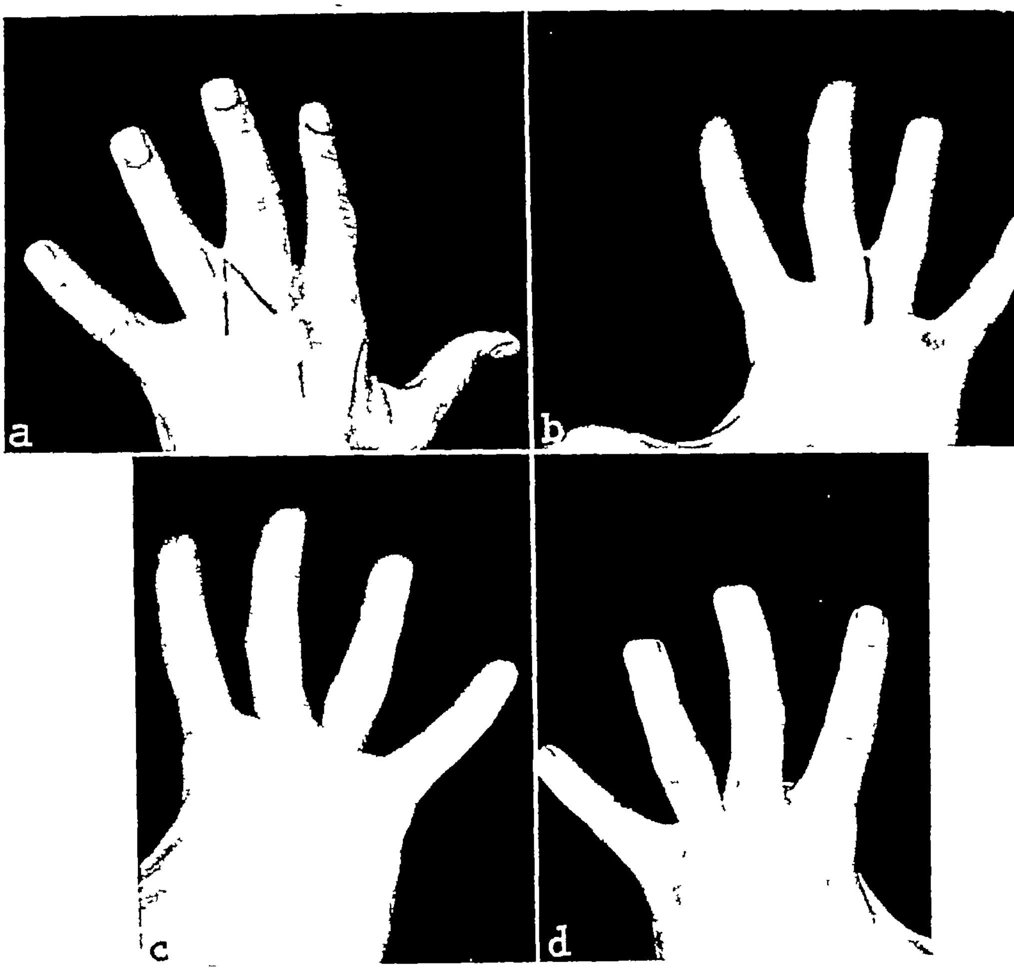
Case 143



Case 143 *a* Boy aged two with fusion of second to fifth finger of his right hand, bony fusion between the terminal phalanges of the fourth and fifth fingers. The remainder of the fusion consisted of soft tissue At birth the fingers were straight but subsequently became flexed due to the shorter finger holding the longer finger back in growth

b A two-stage operation was performed consisting of severance of fusion between the fourth and fifth fingers and third and second fingers, and application of a full thickness graft to cover the raw surfaces in the first stage five months later severance of the fusion between the third and fourth fingers with application of a full thickness graft. Many of the scars along the grafted areas became hypertrophic. X ray treatment softened the scars. Full function of all fingers.

Case 144

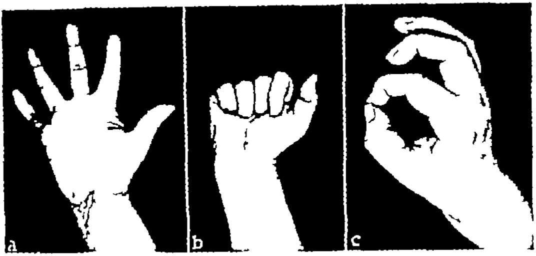


Case 144, *a* Incomplete syndactylism between third and fourth fingers, repaired with a dorsal triangular skin flap (after Zeller) The base of the flap is at the level of the metacarpophalangeal joints, the tip at the level of the proximal interphalangeal joint The flap is mobilized and reflected dorsally

b The fused volar portion is severed longitudinally

c, d In this case, the raw surfaces along the fingers could be covered with the redundant skin after severance of the volar fusion The base of the web was covered by reflecting the dorsal triangular flap to the volar side.

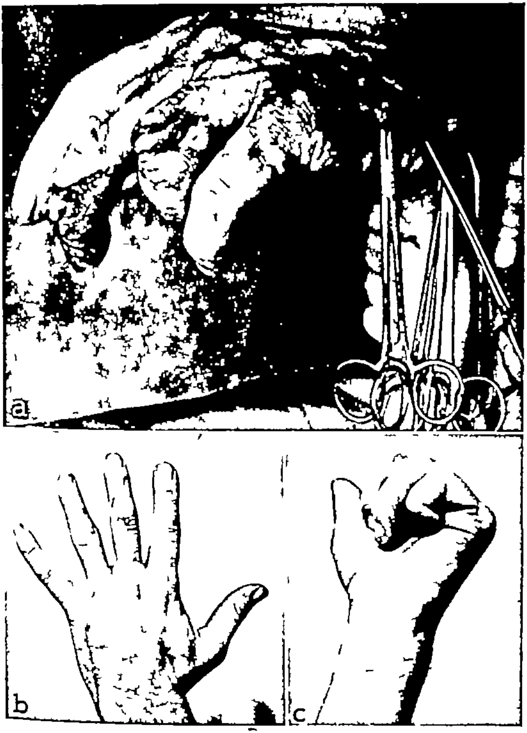
Case 145



Case 145 Patient, aged thirty-one, while window-cleaning, fell through a window and lacerated the right wrist. Preoperative examination revealed separation of the tendons of the musculus flexor carpi radialis flexor carpi ulnaris flexor digitorum sublimis and musculus flexor digitorum profundus of the second third fourth, and fifth fingers separation of the median and ulnar nerves and of the ulnar artery Immediate repair of all structures, ligation of the ulnar artery and vein Immobilization on a dorsal molded plaster cast splint. The splint was temporarily removed on the fourteenth postoperative day and physical therapy including galvanization was started The patient received daily treatments. The splint was worn for three months until the neurological examination demonstrated return of sensory and motor function of the injured nerves. Physical therapy was continued every other day for another six months. At that time, the patient was discharged with full functional return of the injured tendons and nerves

Case 146 Patient's left hand was caught in an electric saw He had extensive lacerations of the dorsum of the hand over fourth and fifth fingers, severance of the two extensor tendons of the fifth finger, compound dislocation of the first interphalangeal joint of the fourth finger and of the terminal joint of the third finger, severance of the extensor tendons of the fourth and fifth fingers at the joint openings; and comminuted compound fracture of terminal phalanx of third finger Immediate repair of the injured structures (one hour after the accident) Immobilization on a volar molded plaster-cast splint The splint was removed after two weeks, and physical therapy was started Return to light work Physical therapy was continued every other day for two months Patient was then discharged Good function of the hand

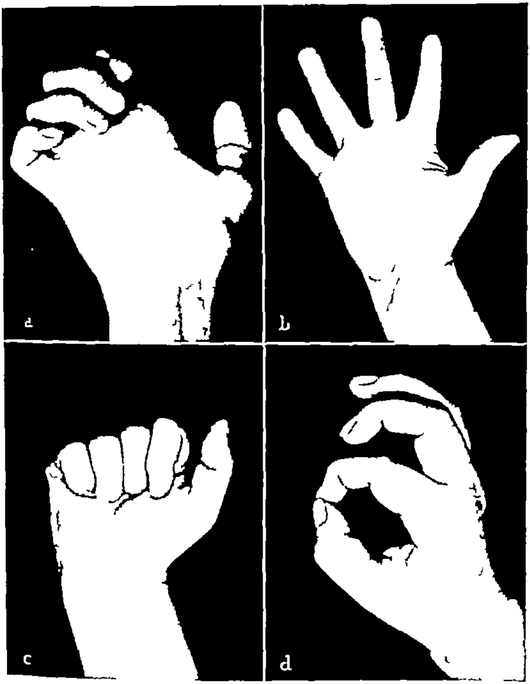
Case 146



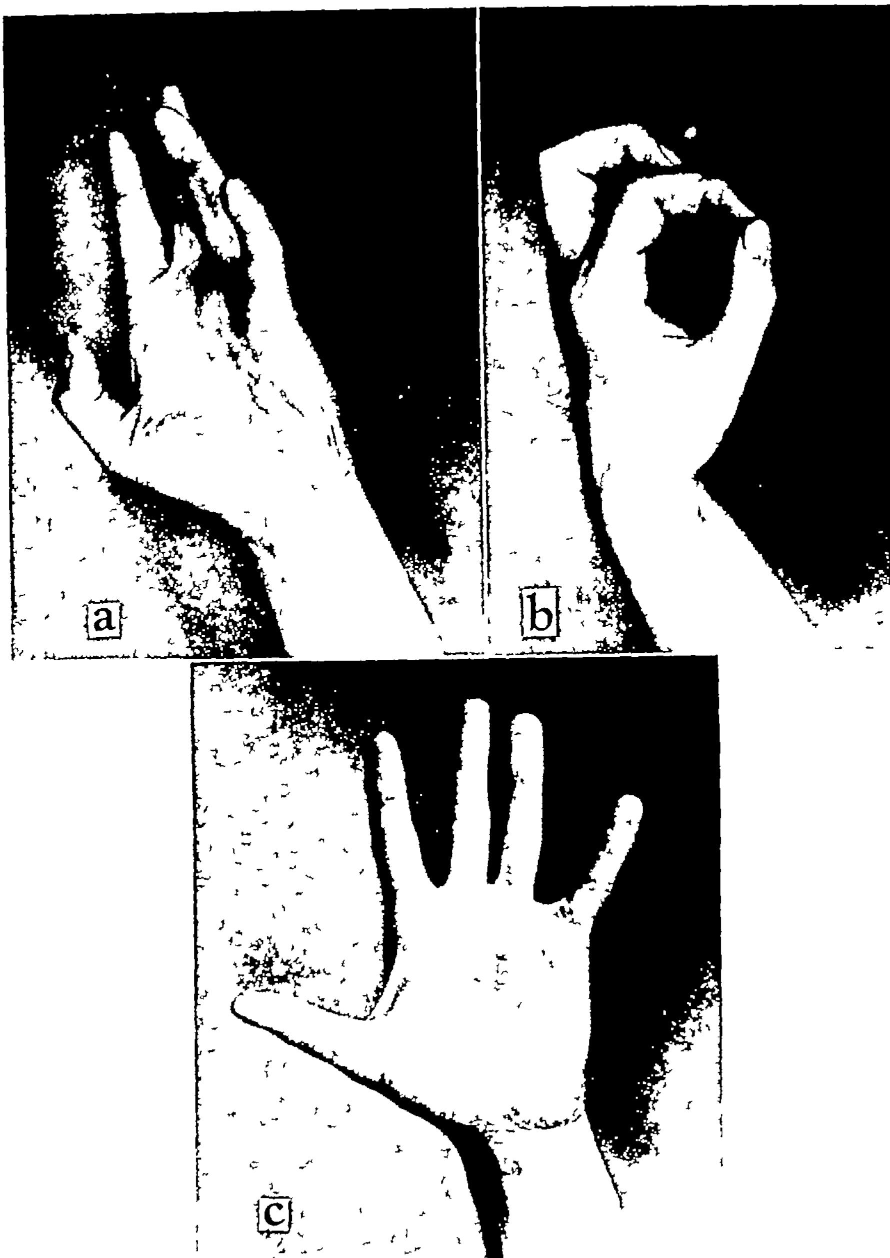
Case 147, *a*. Boy, aged eleven, had a laceration of the tendons of the musculus palmaris longus, flexor carpi radialis, flexor pollicis longus, flexor digitorum sublimis, and musculus flexor digitorum profundus, and of the median nerve and ulnar artery and vein (treated elsewhere). The severed tendons and nerves were repaired. The arm was immobilized for two weeks, and physical therapy instituted. After four months, it became evident that the sutured median nerve was not regenerating. Upon consultation, it was found that at the time of the accident, an injury of the ulnar nerve must have been overlooked. The clinical picture was typical for paralysis of all intrinsic muscles of the hand (see p. 759). When he extended hand and fingers, the latter flexed as shown in *a*. Note wasting of thenar region. An exploratory operation was advised and carried out. The repaired tendons were found intact, but the proximal stump of the median nerve had been sutured to the distal stump of the ulnar nerve. Both nerves were severed from each other. The distal stump of the median nerve and the proximal stump of the ulnar nerve were located. All nerve ends were cicatricial, and had to be shortened for some distance until normal nerve fibers were encountered. Under extreme flexion of the wrist, the corresponding nerve stumps were sutured together. The arm was immobilized on a dorsal molded plaster-cast splint. The splint was temporarily removed three weeks after the operation, and physical therapy and occupational therapy were instituted. First return of nerve function was noticed two months later. The splint was removed.

b–d. Patient's hand had regained almost full function nine months after the second operation.

Case 147



Case 148



Case 148 Patient, aged nineteen, severed flexor pollicis longus of left thumb just distal to the flexor crease of the metacarpophalangeal joint Only the skin wound was sutured

a-c Five months later the divided flexor pollicis longus was replaced with a tendon graft from the long extensor tendon of the fourth toe The tendon was inserted to the terminal phalanx and to the flexor pollicis stump in the wrist

ually severed from its pedicle with the laboratory-clamp technic. The pedicle is now removed from its base with a V shaped excision and the resulting defect closed by suturing the wound edges together The sutur ing of the flap into the defect, however should be delayed for a few days after adjustment of the flap s reversed circulation It should be particu larly delayed if parts or the entire pedicle are left attached to the flap and are to be used for covering the defect. In such a case after a few

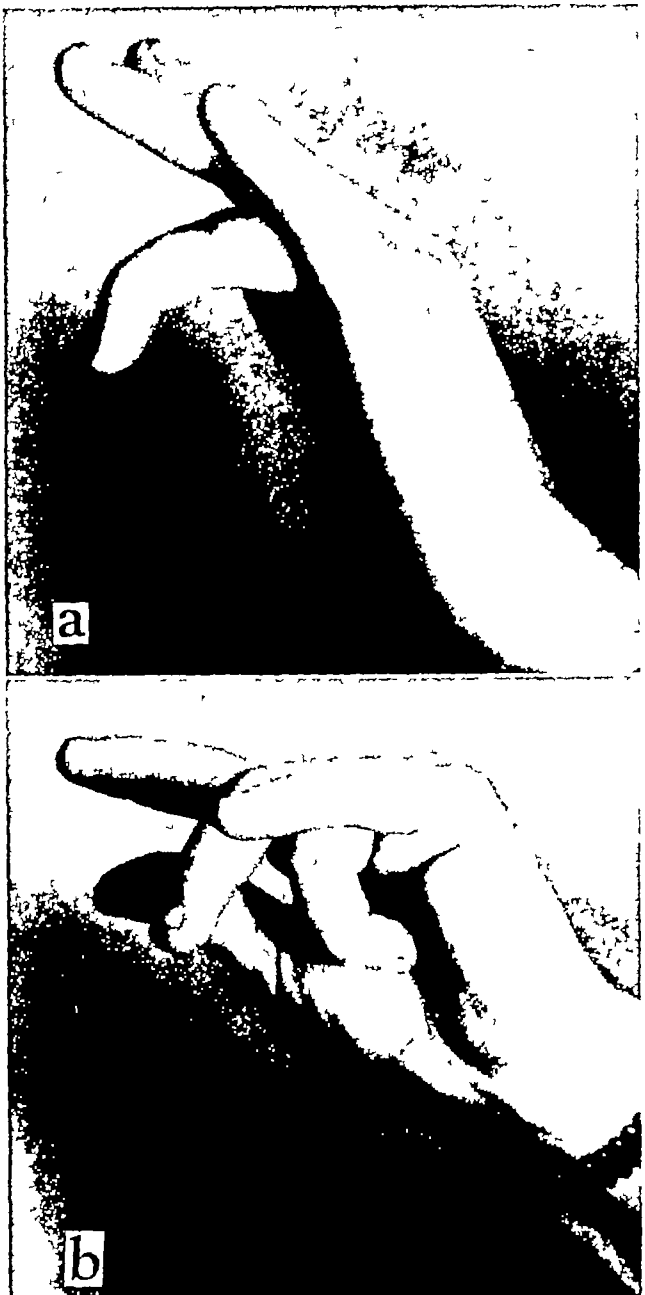
Fig 48: Partly tubed flap. Peripheral end in stage of gradually being severed. Untubed part has been raised with exception of middle bridge to which laboratory clamp is applied. Raised part has been returned and sutured. Middle bridge is gradually crushed by tightening clamp.

days or weeks depending upon the length of the remaining tube the tube is incised along its scar (seam) the tube is opened and spread out flat to fit into the defect. (For the use of tube flaps see Cases 6 p 851 11 p 860 39 p 900 106 pp 990-993 103 p 986)

The Partly Tubed Flap

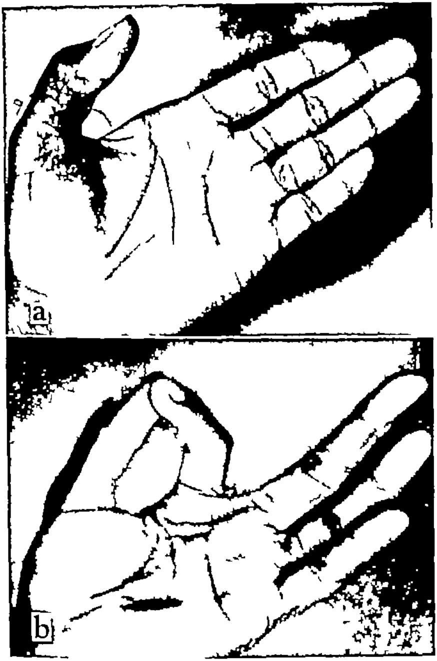
In this type of flap the peripheral end—that is, the part of the flap which is to be utilized for covering the defect—remains untubed, and is returned to its original site and sutured in place. After about three weeks

Case 150



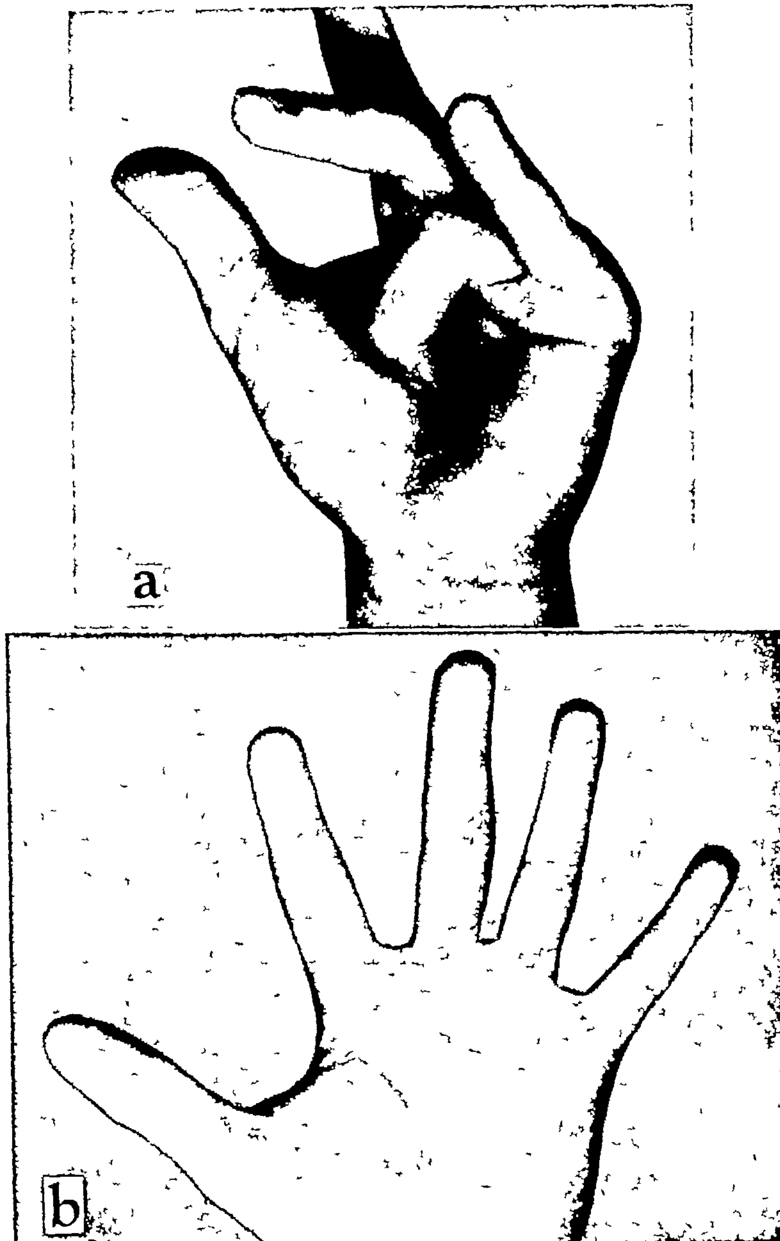
Case 150, *a, b* Severance of the profundus tendon of fourth finger over the middle phalanx Six weeks after tenodesis of distal stump of severed profundus tendon to bone of middle phalanx to hold terminal phalanx in 45 degree flexion permanently (Compare with case 149)

Case 149



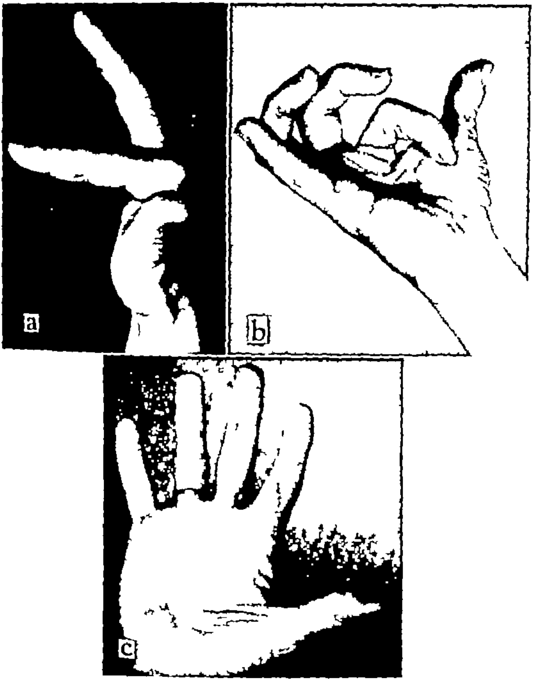
Case 149 Division of flexor pollicis longus. Primary repair had been attempted but had failed. The second operation revealed much scar tissue and for this reason a tendon grafting operation seemed to be contraindicated. A tenodesis was performed by incorporating the distal stump of the flexor pollicis longus into the first phalanx holding the terminal joint in 45 degree flexion The pull-out wire method after Bunnell was used to hold the tendon in a canal which was drilled through the phalanx. Further immobilization of this joint was achieved by insertion of an intramedullary Kirschner wire (see Fig 387 p 728) The wire was removed later

Case 152



Case 152, *a, b* Patient, aged thirteen, received a rupture of the profundus tendon of fourth finger while tackling during football Two months later the sublimis tendon was sacrificed and the profundus tendon replaced with a tendon graft from the long extensor tendon of the fourth toe Result five months after operation

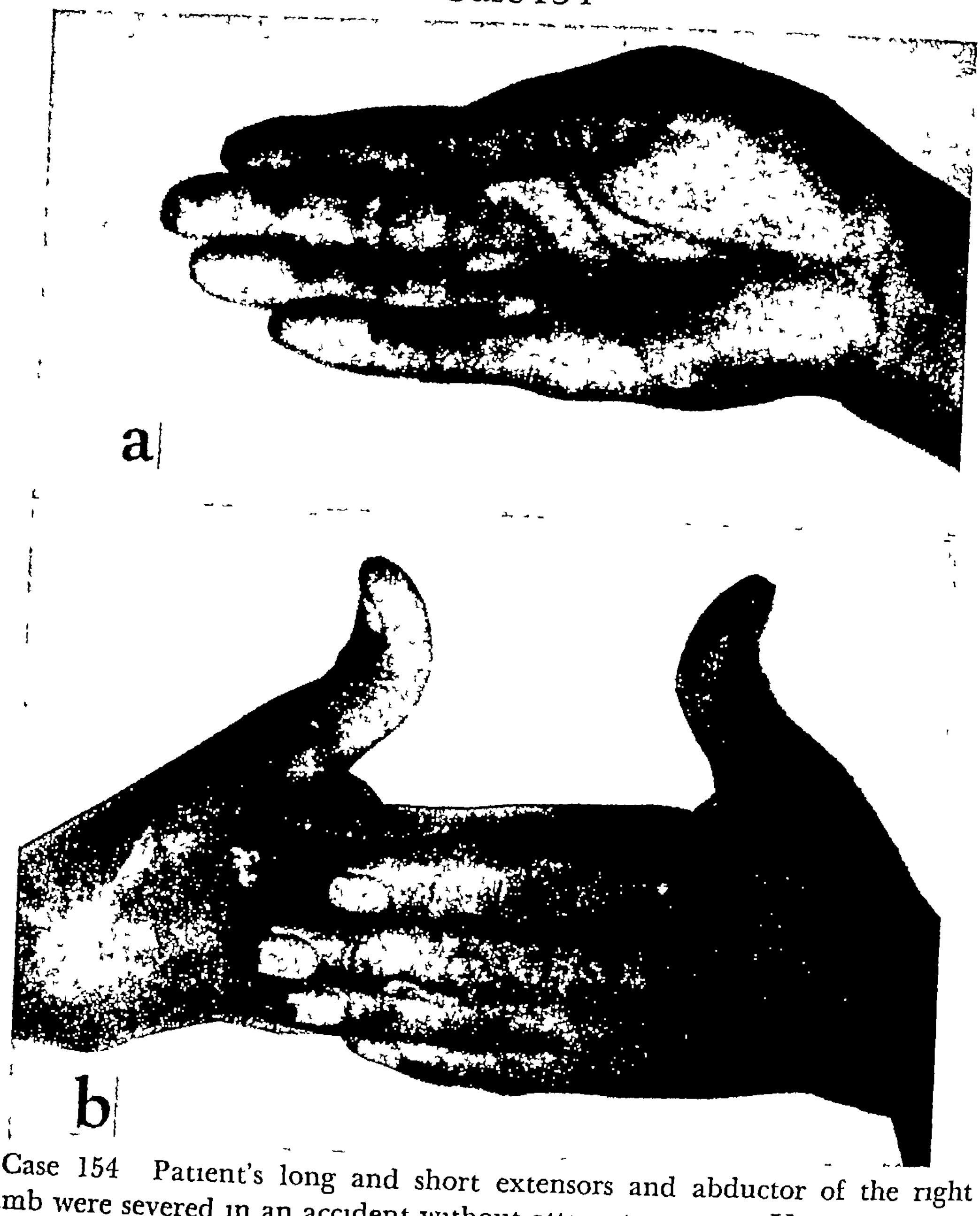
Case 151



Case 151 *a* Patient, aged twenty seven with severance of profundus and sublimis tendons of right index finger in level of the web

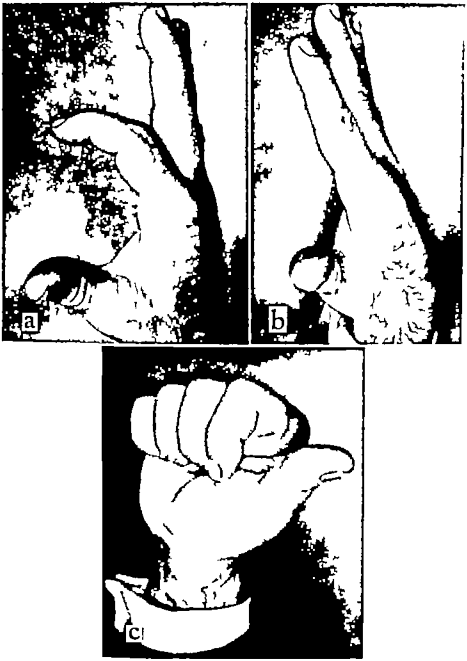
b c After replacement of both tendons with a tendon graft from the sacrificed sublimis tendon

Case 154



Case 154 Patient's long and short extensors and abductor of the right thumb were severed in an accident without attempt at repair Upon operation several months later the six tendon stumps and the severed superficial radial nerve were identified The tendon stumps were frayed and needed much shortening, end to end suture became impossible and tendon grafting had to be employed The proximal end of the abductor pollicis was used as a graft The distal ends of the extensor pollicis longus and brevis were sutured together and the gap between these combined tendons and the proximal stump of the extensor pollicis longus was bridged with the tendon graft To increase the motor power the extensor pollicis brevis was sutured upon the extensor pollicis longus The superficial radial nerve stumps were approximated The hand was immobilized in cock-up position of the wrist with extension and opposition of the thumb for three weeks Functional result (*a*) before, and (*b*) four months after the operation

Case 153



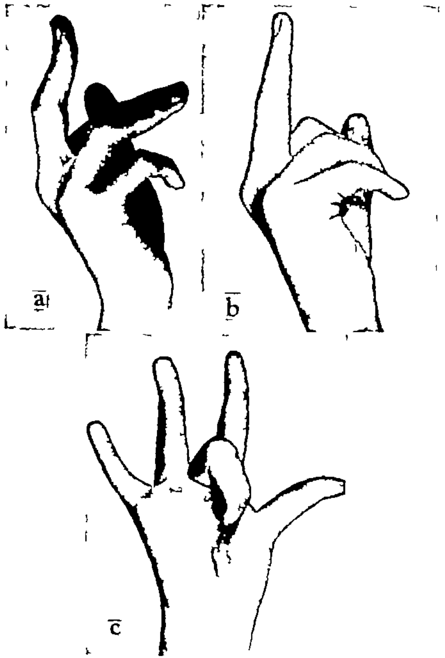
Case 153 *a* Patient, aged thirty nine fell on a piece of glass and severed the extensor tendons of the second finger The tendon became adherent and prevented flexion as well as extension of the finger

b c After tenolysis and bridging the tendon defect with a tendon graft from the long extensor tendon of the fourth toe

Case 156, *a, b* Patient, aged twenty-six, came in touch with a high tension wire and received deep extensive burns of the left hand The soft tissue of the flexor surface of the forearm and the midpalmar space sloughed out and were débrided This resulted in loss of the musculus flexor carpi radialis, flexor pollicis longus, the median nerve, and long flexors of second, third, and fourth fingers The defect was closed with an abdominal flap

c, d Two months later tendon grafting was performed to replace the action of the profundus tendon of the second, third, and fourth fingers The peroneus brevis tendon was used as a graft and was sutured to the distal end of the profundus muscle stump in the forearm The other end was split into two strands, one strand was sutured to the profundus tendon of the second finger and the other one to the profundus of the fourth finger The profundus of the third finger was sutured into the point of division of the graft Two months later opposition of the thumb was restored by transferring the extensor pollicis brevis to the severed and rerouted extensor carpi ulnaris The latter was rerouted just proximal to the ulnar epiphysis

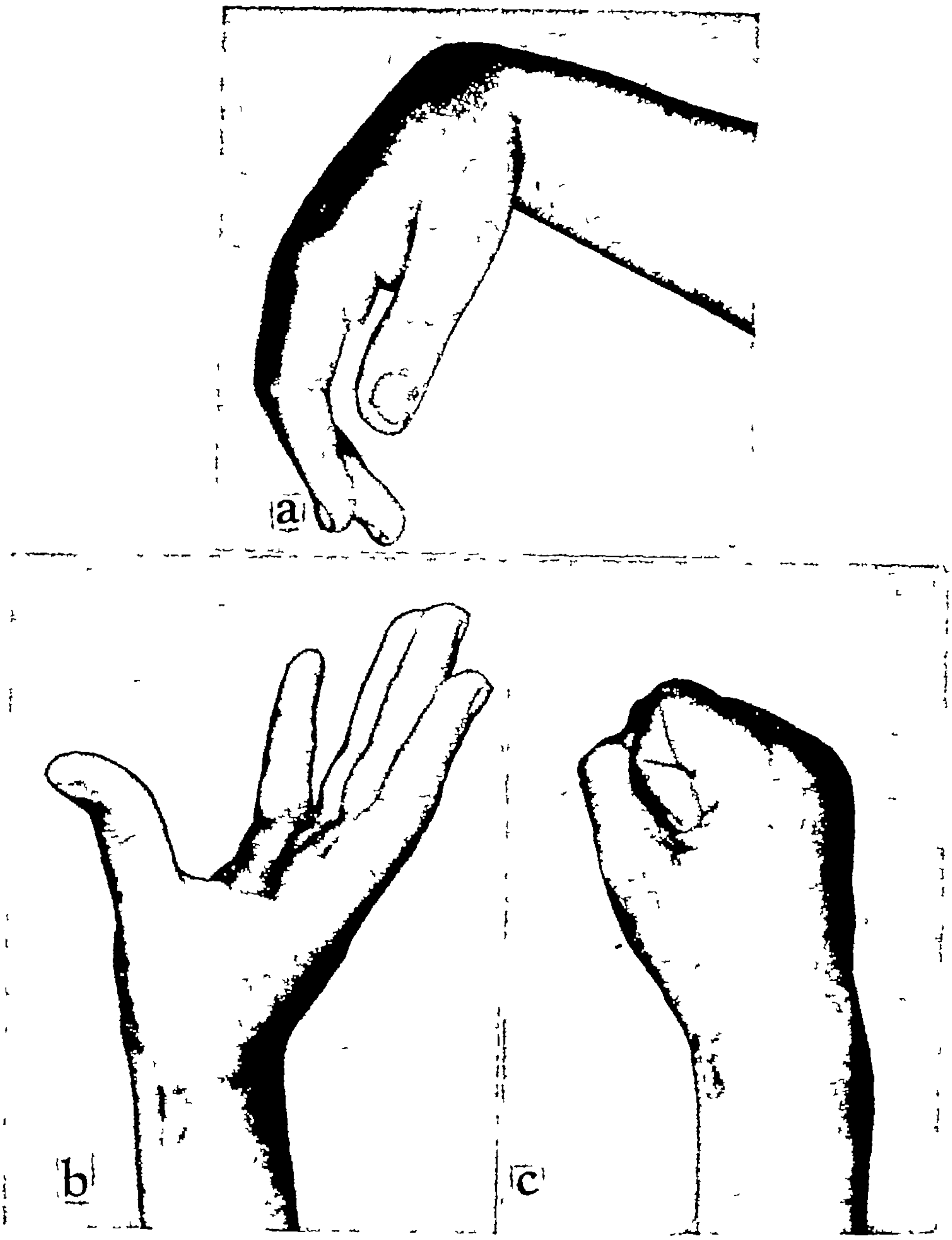
Case 155



Case 155 *a* Button hole injury due to ruptured distal aponeurosis over first interphalangeal joint.

b c After transferring the forward displaced extensor slips to the dorsal side of the finger and holding them together with sutures. Closure of the rent in the capsule of the first interphalangeal joint. Repair of the ruptured extensor tendon over this joint.

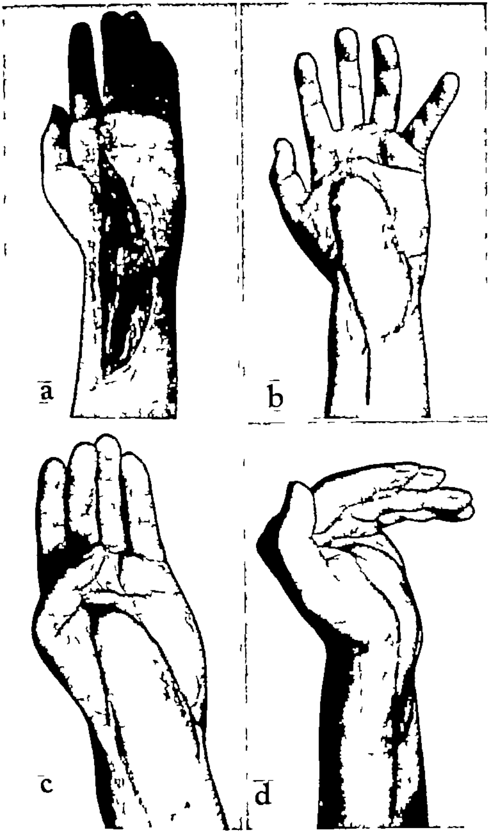
Case 157



Case 157, *a* Boy, aged twelve, with irreparable radial palsy from severance of the radial nerve in the right upper arm after a previous accident The nerve ends had been sutured together but the nerve did not regenerate. Thirteen months later a tendon transfer was performed consisting of transfer of the flexor carpi ulnaris tendon to the extensor tendons of second to fifth fingers and transfer of the palmaris longus tendon to the severed extensor pollicis longus tendon

b, c Function of wrist and fingers was almost normal three months after the operation

Case 156



the untubed part is raised again and its peripheral attachment (peripheral pedicle) narrowed from both sides by incisions, a laboratory clamp is attached to the middle bridge (Fig 48, Case 14, p 864) and the flap bed possibly skin-grafted All wound edges are then sutured together The circulation is now interrupted by gradual tightening of the clamp, as already described After the middle bridge has been crushed completely, the flap may be ready for transfer

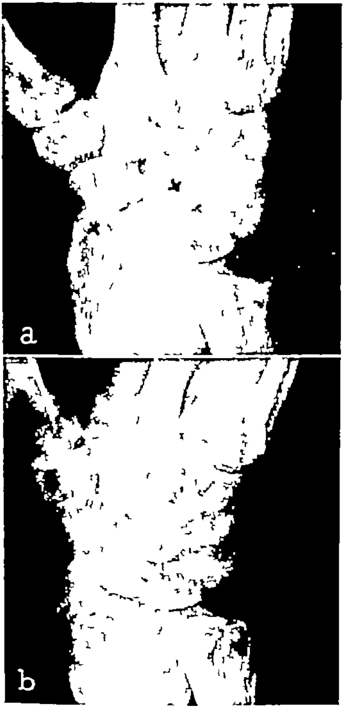
The advantage of leaving the peripheral pedicle untubed is that it shrinks less than when tubed It is a well-known fact that the tissues which are included in a tube shrink transversely, so that the full original width cannot be obtained after the tube is spread out flat, furthermore, when a flap has to be lined, it can more easily be folded upon itself, if such is the plan (Case 14, p 864) When skin grafts are to be used for lining, the lining can be more conveniently attached to the raw surface of the flap than would be the case if the entire flap were tubed and had to be opened The skin graft should be applied at the time the untubed part is raised and the laboratory clamp applied The donor area may be skin-grafted at the same time After the skin-grafted pedicle is sutured back in place, it acts like a pressure dressing

The Thoracoepigastric Tube Flap

Blood Supply: The longest and widest flap which can safely be formed is from the thoracoepigastric region, reaching from the axilla to the ligamentum inguinale (Webster) (Figs 44, 49, Case 106, p 990) This region has an abundant blood supply. The largest and longest arteries of the body that course outside the deep fascia to supply the skin and subcutaneous tissue start at each end of this region, and approach its middle portion (above the arteria thoracalis lateralis and suprema; below: the arteria epigastrica superficialis and inferior and arteria circumflexa ilium superficialis) Furthermore, the longest, largest, and most superficial cutaneous veins of all available donor areas are located in the thoracoepigastric region The course of the vena thoracoepigastrica is visible through the skin in many persons, or can be made visible by washing the area with alcohol.

Procedure: The course of the vena thoracoepigastrica should be marked with one of the aniline dyes. Using this line as the longitudinal center line, the width of the flap—as previously determined (8 to 10 cm. [$3\frac{3}{16}$ to $3\frac{15}{16}$ inches] in adults)—is marked out on each side of it, as described previously (Fig 42). The two parallel incisions are now made, and the flap is raised between the superficial and deep layers of the deep fascia After thorough hemostasis, the tube is formed in the usual way.

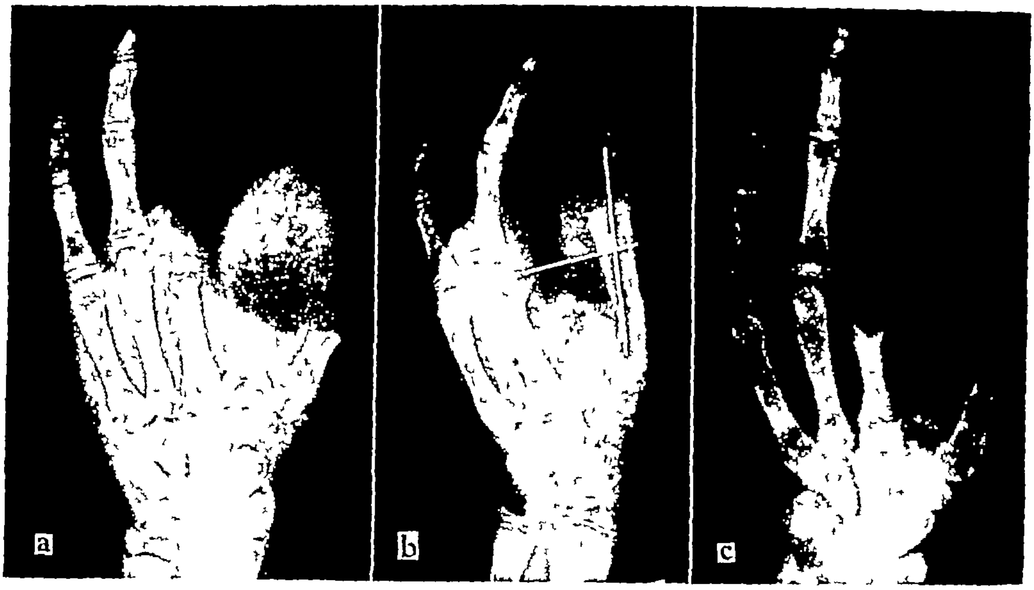
Case 158



Case 158 *a* Patient, aged twenty-eight, with nonunion of os naviculare of two months duration Fracture line x–x in roentgenogram. Both fragments revealed same density hence, appeared to be alive The wrist was immobilized in a plaster cast in cock up position for three months no evidence of healing after that time

b A bone-pegging operation was performed (p 776) and the wrist immobilized After three months the x ray examination revealed complete union

Case 159



Case 159, *a-f* Boy, eleven and one-half years of age, lost radial half of right hand as result of an explosion (*d*)

A rather large abdominal flap was transplanted in one stage to provide coverage of the raw surface and an extension to receive later on a bone graft to lengthen the first metacarpal stump Eight days later the flap was partially separated and a laboratory clamp was applied to the remaining pedicle to gradually crush the pedicle Five days later the flap was severed Four days later the flap was adjusted in place (*e*)

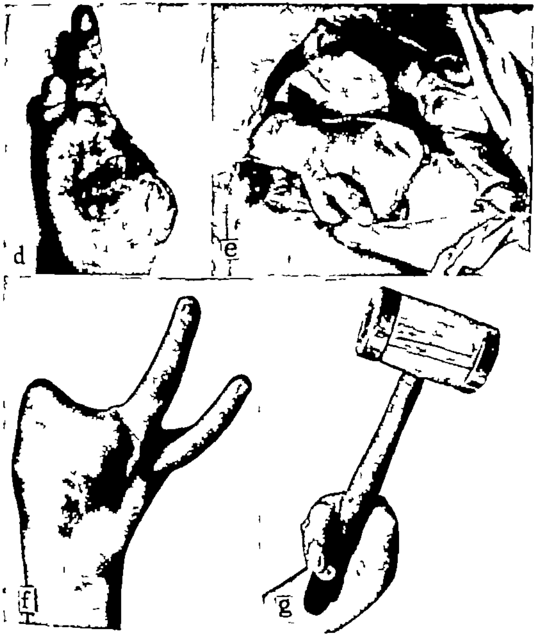
Roentgenograms Metacarpal stumps over which the soft tissue flap is faintly outlined (*a*)

Five months after the flap transfer a metatarsal bone (the fifth) was placed upon the stump of the first metacarpal bone and transfixed with intramedullary wires (*b*)

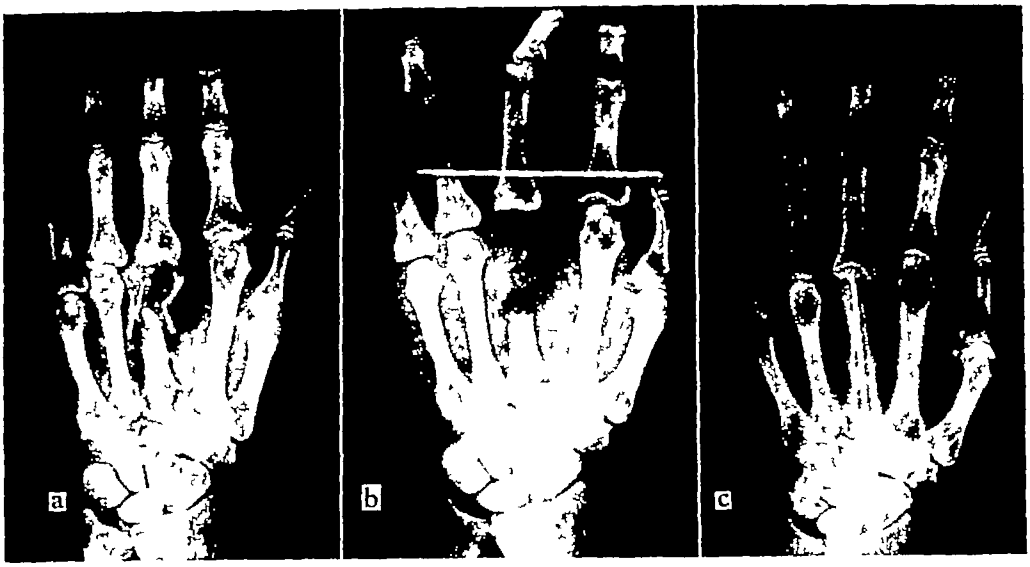
Three months later the horizontal cross pin was removed and after another three months the vertical pin (*c*)

Demonstration of functional result (*f, g*)

Case 159



Case 160



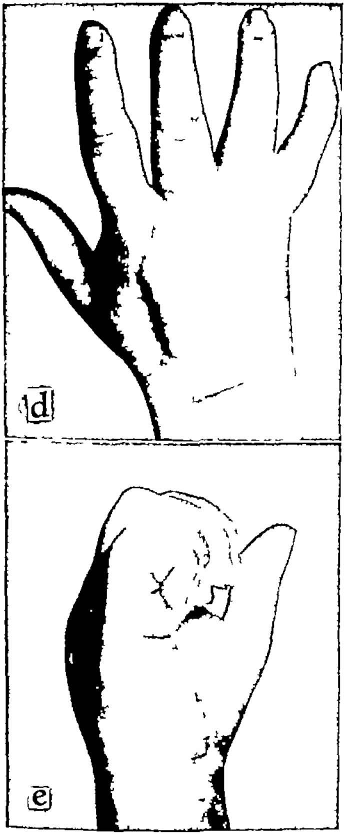
Case 160, *a* Patient, aged sixty-two, was shot accidentally in the dorsum of the right hand The injury resulted in extensive loss of surface tissue and a badly comminuted and compound fracture of the third metacarpal bone

b Distal two-thirds of the third metacarpal bone was removed The third finger was suspended upon the first phalanges of the second and third fingers by cross pinning The pin was laid just beneath the webs of the finger and buried subcutaneously A flap was transplanted from the abdomen in one stage It was clamped ten days later and severed two days later, and adjusted in place five days later

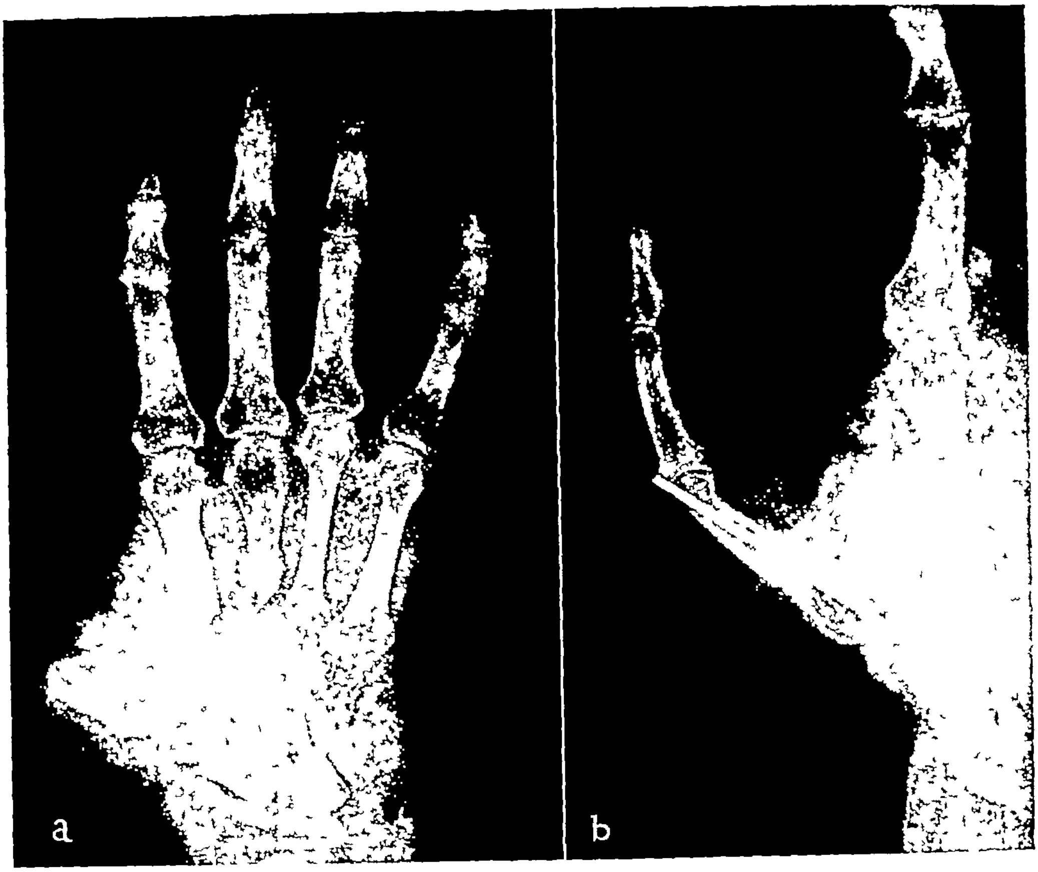
c Three months later the third metacarpal bone was replaced with the fifth metatarsal bone and was stabilized with a longitudinal intramedullary wire and a cross pin through the sides of the metacarpals This cross pin was removed five months later, while the vertical wire is still in place eight years after the accident.

d, e Functional result

Case 160

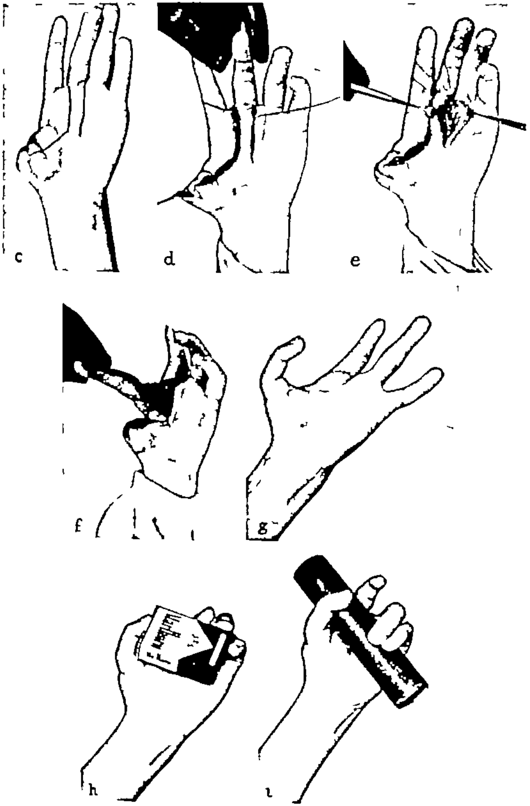


Case 161



Case 161 Patient, aged forty-six, sustained a crushing injury to his left hand with loss of the thumb (*a*) The destroyed soft tissues of the thenar region and web were replaced with an abdominal flap (*c*) There was marked impairment of motility in all finger joints To increase the function of this badly damaged hand, a thumb substitution operation was considered Since the index finger showed distinct evidence of impairment of circulation (prolonged paleness after tourniquet test) the third finger was selected to replace the thumb with the Lucksch-Hilgenfeldt procedure (*d*) Flap and incisions towards the thumb bare outlined (*e*) Exposure of the neurovascular bundle (*f*) The finger is being moved to the stump of the thumb metacarpal (*b*) Fixation of the transposed finger to the stump of the first metacarpal with an intramedullary wire An additional cast was applied for five weeks Then the profundus tendon of the third finger was shortened It could not be joined with the flexor pollicis longus since the latter was frayed and adherent The intramedullary wire was removed nine weeks after the finger transfer (*g*), (*h*), and (*i*) depict the functional result six months after the transfer In spite of a previous tenolysis adhesions recurred preventing the fingers from fully functioning The new thumb has sufficient sensitivity, although some of the sensitivity is projected along the radial side of the fourth finger

Case 161

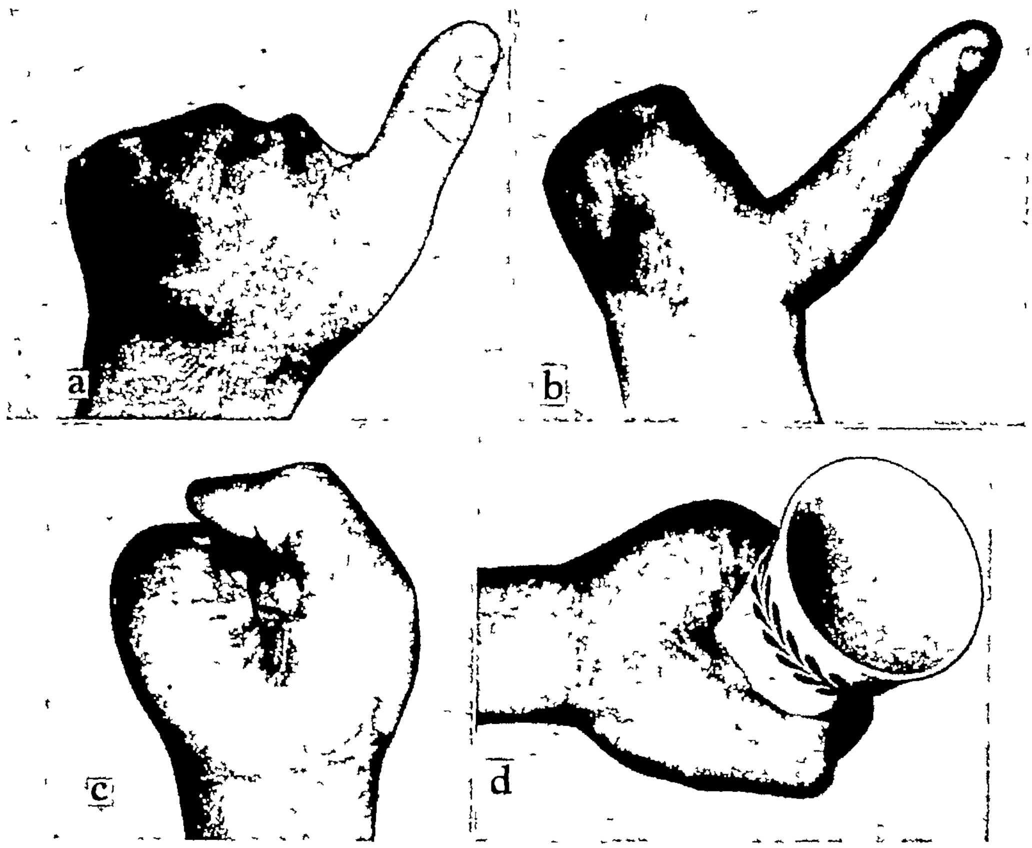


Case 162

Case 162, *a* Patient, aged thirty-five, with traumatic amputation of the right thumb through the proximal phalanx, traumatic amputation of index finger through the middle phalanx, and of third, fourth, and fifth fingers through the metacarpals

b, c An operation for phalangization was performed (p 797) to create a cleft between the first and second metacarpal bones

Case 164

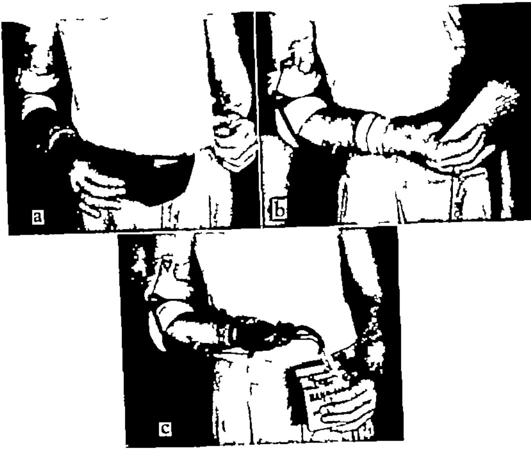


Case 164, *a* Traumatic disarticulation of the second, third, fourth, and fifth fingers

b The second metacarpal was removed An operation for phalangization was performed with removal of the first interosseous muscle and portion of the adductor muscle (p 797) At the same time excision of the articular surface of the third, fourth, and fifth metacarpal and transplantation of an abdominal flap was carried out to close the raw surface over the metacarpal stumps The flap was severed eleven days after transfer and three days later adjusted in place

c, d Functional result

Case 165



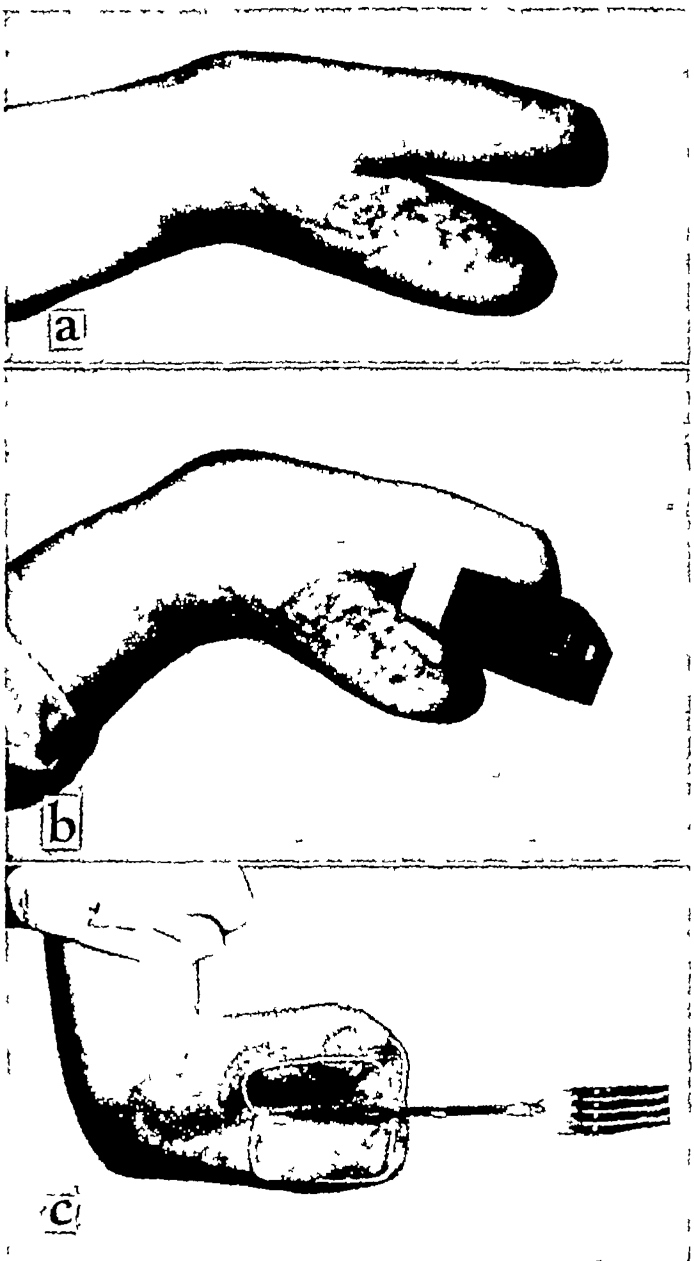
Case 165 *a-c* Patient, aged eighteen years, who had right forearm amputated through the distal third after an extensive crushing injury A cineplasty was performed through the biceps muscle. Demonstration of functional result. Hand and hook units are interchangeable.

If there is excess of fat tissue extending beyond the skin edges, it is trimmed away to facilitate closure. The secondary defect is now closed by wide and extensive undermining of the skin subcutaneous tissue and superficial layer of the deep fascia on each side of the defect and by suturing first the superficial layer of the deep fascia and then the skin edges together or by skin grafting

b

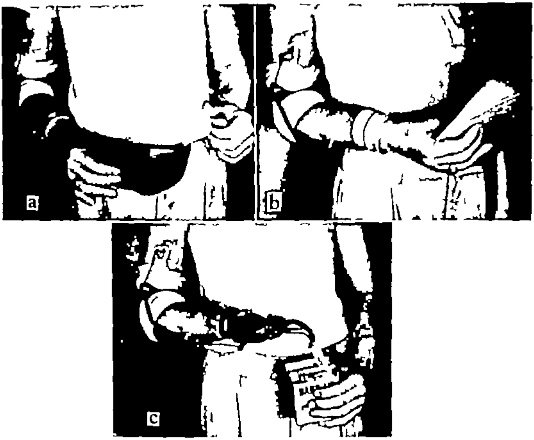
Fig. 49 a. Method of insuring adequate blood supply in long tube flaps by making one parallel incision of flap (median) uninterrupted and one (lateral) interrupted in its wide portion, thus leaving fairly wide bridge attached to one side of flap. b: At end of operation, soft intestinal clamp is applied. If color of flap remains normal, bridge is severed and flap completed otherwise bridge is left attached for additional two weeks.

Case 166



Case 166, *a-c* Patient, aged sixty-three years, who had forearm amputated just above the wrist after severe crushing injury of the hand A Krukenberg forcepization operation was carried out Demonstration of functional result.

Case 165



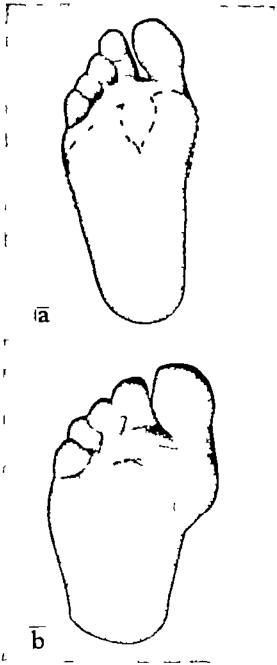
Case 165 *a-c* Patient, aged eighteen years who had right forearm amputated through the distal third after an extensive crushing injury A cineplasty was performed through the biceps muscle Demonstration of functional result. Hand and hook units are interchangeable

Case 168, *a* Patient, aged thirty-three, had a plantar wart on left foot for fifteen years Numerous conservative methods, such as radiation and cauterization, had failed to cure the lesion Hence, radical excision and closure of the defect with a pedicle flap became advisable The flap was prepared at the right thigh, as described on p 833 In the first stage, it was elevated between two parallel incisions Clamping of the peripheral pedicle resulted in discoloration of the flap Hence, the flap was returned to its original site After three weeks, it was again elevated The median pedicle was narrowed from each side, leaving a middle bridge to which a laboratory clamp was attached By tightening the thumbscrew, the remainder of the pedicle was gradually crushed within five days Two weeks later, the entire flap was raised The peripheral parts changed color, hence, the flap was again returned

b One week later, the flap was again elevated, the flap bed at the thigh was skin-grafted, and the flap was transplanted after excision of the plantar wart, which had reached the first metatarsophalangeal joint (For technic of immobilization of the crossed legs, see p 833)

c One week after the transfer of the flap, a laboratory clamp was applied to the pedicle, which was gradually crushed It was severed eleven days after the transfer The cast was removed The free end of the pedicle at the thigh was adjusted in place, while the free end of the flap at the foot was sutured in place ten days later. The patient was not permitted weight-bearing for four weeks She was last seen seven years after the last operation She had no pain and no limp

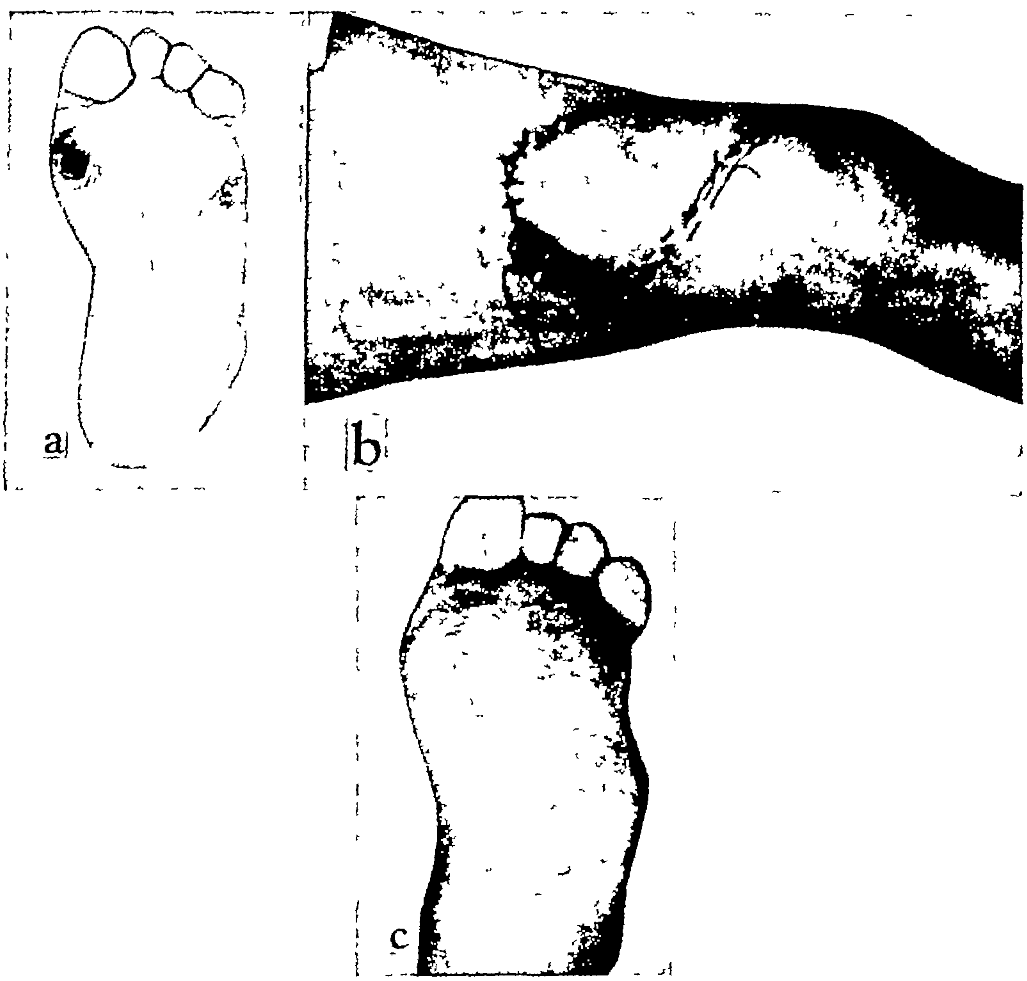
Case 167



Case 167 *a* Patient, aged thirty five with plantar wart of right foot treated by irradiation. After two years the wart returned and the area became very painful The involved area was excised and skin grafted The skin graft, however broke down after full weight bearing The area was then excised and closed by sliding flaps—lines of excision as well as flaps are outlined.

b Three months after operation One year later patient notified author by letter that there were no symptoms and no evidence of recurrence of the plantar wart.

Case 169

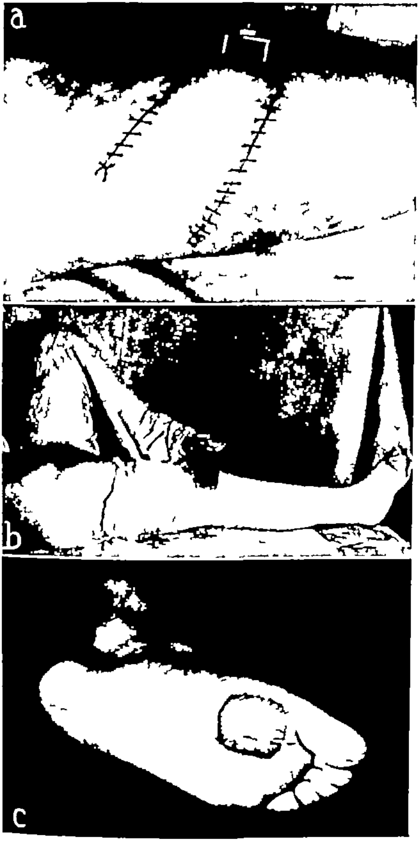


Case 169, *a* Patient, aged fifty years, developed a plantar wart over the fifth metatarsophalangeal joint Plantar wart was excised, fifth toe removed together with head of fifth metatarsal and the redundant skin was used to close the defect The skin, however, broke down and plantar wart recurred A few months later a second plantar wart developed over the second metatarsophalangeal joint Patient was then referred to the author

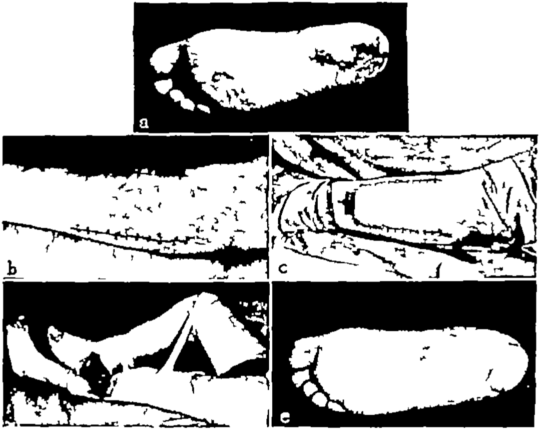
b It was decided to excise the whole area of the forefoot and transplant a cross-leg flap from the thigh of the other side The flap was mobilized in stages, first between two parallel incisions Seven weeks later flap was again mobilized between the two parallel incisions and the lateral pedicle was narrowed, with application of a laboratory clamp to the remainder of the pedicle Pedicle was gradually crushed, and was severed one week later The thigh flap was elevated two months later and returned since the peripheral end became cyanotic Six weeks later the flap was transplanted Eight days later application of clamp, four days later severance of the flap, three days later adjustment of the flap

c Condition of flap several months later

Case 168



Case 170



Case 170 *a* Patient aged fifty two referred to the author for treatment of a deep decubital ulcer at right heel from pressure of plaster cast (original injury compound fractures of right leg)

b A flap was raised from lateral surface of left leg between two parallel incisions Clamping of the peripheral pedicle caused marked cyanosis of the flap Hence the flap was returned to its original site.

c After six weeks the flap was raised again its peripheral pedicle narrowed by severing one third from each side. A laboratory clamp was applied to the middle third and the flap was returned to its original site. By gradually tightening the clamp the remainder of the peripheral pedicle was crushed within five days, and the clamp removed Two weeks later the entire flap was raised The *peripheral end was discolored hence the flap was returned once more*

d One week later the flap was raised. The color did not change hence, the flap was ready for transfer Flap bed was skin-grafted The ulcerated area at the right heel was excised the right leg crossed the flap sutured into the defect. Both legs were immobilized in a plaster cast (For technic of application of cast, see p 833)

e Seven days later a laboratory clamp was applied to the pedicle of the flap and the pedicle was gradually crushed within three days. The pedicle was then severed and the cast removed. One week later the free end of the pedicle at the left leg, as well as the free end of the flap at the right heel was adjusted in place Weight bearing was not permitted for four weeks.

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Dressings and Postoperative Treatment· Dressings and postoperative treatment are the same as previously described (p 83) The time interval, however, between formation of the tube and separation of one of its pedicles should be much longer than in flaps of ordinary length (two to three months), the separation should be gradual, by the laboratory-clamp technic.

Thoracoepigastric Flap in Obesity: If the thoracoepigastric flap is made in a patient with excessive fat, it may be necessary to cut through the subcutaneous fat between the skin and the superficial layer of the deep fascia in order to lessen the thickness of the subcutaneous tissue and so make possible the closure of the tube by suturing without excessive pressure By such a step, the deep arteries and their accompanying veins are cut Webster advises modifying the procedure under such circumstances by using one of the safety procedures described in the following chapter, preferably the one devised by himself

Measures for Insuring Adequate Blood Supply in Long Tube Flaps: Generally speaking, a tube flap should not be made longer than from 20 to 30 cm (7⅞ to 11$^{13}/_{16}$ inches). If it has to be made longer, particularly in obese patients, certain measures have to be taken to secure an adequate blood supply. There are three possibilities available·

Lengthening in Two Stages A tube flap of proper secure length is fashioned in the first stage and lengthened to the desired extent in a second stage, from ten to fourteen days later

Interrupted Tube-Flap Method (DeRiver): The two parallel incisions for the formation of the tube flap are interrupted every 8 8 cm (3½ inches) by several "jumps" or bridges, these skin bridges are 0 6 cm. (¼ inch) wide In this way more abundant blood supply is furnished. After from ten to fourteen days, the lateral attachments are separated and sutured together, thus the tube is completed This method can be modified by the formation of one bridge, but a wider one left in the middle of the flap on either side

Unilateral Bridge Attachment (Webster) The principle of this method consists in making one of the parallel incisions of the flap uninterrupted and the other one interrupted in its wide portion, thus leaving a fairly wide bridge attached to one side of the flap (Fig 49, *a*) After from ten to fourteen days, the bridge can be separated and the tube completed The author (May) found that sometimes the second stage could be undertaken at the end of the first stage, thus, a second operation became un necessary for the following reason He had left the flap attached to a unilateral bridge for purposes of safety, a soft intestinal clamp was applied to the bridge (Fig 49, *b*) If the color of the flap remained normal,

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the bridge was separated at the end of the operation and the flap completed otherwise the bridge was left attached for another two weeks

The unilateral bridge attachment is the preferred method. One of its main advantages is that the tissues on both sides of the defect and on both sides of the flap can be brought together to such an extent that the secondary defect can be closed almost entirely and the tube practically formed in its entire length during the first stage

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III

WOUND-HEALING AND TREATMENT OF WOUNDS

A WOUND may be defined as a traumatic separation of the skin, mucous membrane, or the surface of an organ. A wound is either simple, if no deeper tissues are involved, or compound, involving such structures as muscles, nerves, tendons, and bones The form of the wound depends upon its cause The wound due to cuts has smooth edges, does not show involvement of the surroundings, and bleeds freely It is linear if the cutting force penetrated vertically, it is flaplike if penetrated obliquely. Wounds due to contusion have irregular edges These edges are bluish and elevated, and may be undermined, forming pockets The surroundings of the wound show abrasions and subcutaneous hematomas, and may have insensible areas Bleeding may be minimal Wounds due to tear show an irregularity of their edges, as in contused wounds, but less involvement of the surroundings

The immediate consequences of a wound are local pain and bleeding, and—in extensive deep wounds—general shock, collapse, and anemia.

The Healing Process

Before discussing the treatment of wounds, it is necessary to speak of the various processes which lead to wound-healing, since a rational treatment of wounds ought to further the healing process as well as to prevent additional damage and infection Allgower of Switzerland recently published results of a series of interesting and stimulating experiments on wound healing He not only could verify the well-known findings of Alexander Maximow and his school in the early part of the century, which established the totipotency of leukocytes and their progenitors as

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elimination of disturbing factors and corrections of the deficiencies accelerate the healing process (see pp 114, 127) The extent of the damage must also be considered The greater the amount of tissue necrosis, the longer time is required for phagocytosis and repair Hence, a properly débrided and excised wound is apt to heal quicker and with fewer complications than a wound that contains much devitalized tissue Furthermore, a wound heals quickest and with fewer complications if it heals by primary intention, i e , without the formation of granulation tissue This is the rule in wounds in which the wound edges can be closely coapted, but it can also be brought about in extensive wounds if it is possible to apply a skin graft for immediate coverage A more detailed discussion of wound-healing beneath skin grafts is found on p 25 If a wound is left to heal by secondary intention—i e., for granulation tissue to develop—epithelization will be only partial, as already mentioned, and more or less scar formation is the rule A scar can become harmful if it contracts or, owing to instability, breaks down Hence, wound-healing by secondary intention, useful as it may be in closing the raw surface, can be harmful if it results in contracting or unstable scars The latter may be prevented by early coverage of the granulations with skin grafts

Treatment of Wounds

In treating traumatic wounds, one must realize two facts· first, a traumatic wound is an emergency, second, a traumatic wound is contaminated Through the trauma, organisms are carried from the surrounding skin, the cloth, or the medium that produced or contacted the wound, into the wound. These organisms remain along the wound tract and on the necrotic tissue for about six hours (Friedrich). Later on, they adapt themselves to the new surroundings, and commence to multiply and to penetrate into the deeper tissue and lymph channels, the stage of contamination thus passing over the stage of infection Therefore, the first six hours constitute a period of relative safety, and it is desirable to treat a wound within this time. The emergency arises from complications, such as hemorrhage and shock. Wound therapy has two general divisions emergency treatment and final, or definitive, treatment

EMERGENCY TREATMENT

Anyone who undertakes the emergency treatment of a wound should be cognizant of the fact that he harms more than helps if he secondarily infects the contaminated wound by touching it with the fingers or by covering it with soiled cloths, or if he uses antiseptics which harm the cells of the tissues more than the organisms they kill.

the originators of any healing process but also substantiated the fact of the nuclear blood cell being the unequivocal source for the granulation tissue of wound repair We distinguish healing by primary and by secondary intention the morphohistological processes of which have been masterly described by Marchand A wound heals primarily as a rule if its edges are healthy and remain in close approximation to each other If however the edges are devitalized or separated or become so the resulting defect has to be first bridged and filled by granulation tissue before it finally becomes a scar

Healing by Primary Intention Morphological changes in primary wound healing start with a dilatation of the vessels of the closely approximated wound edges Plasma escapes and fills the spaces between the edges The plasma soon changes into fibrin the latter is invaded by polymorphonuclear leukocytes and histiocytes which by phagocytosis and autolysis remove the necrotic tissue foreign bodies and organisms (destructive or lag phase of wound repair) Almost simultaneously capillaries and fibrous-tissue cells (fibroblasts fibrocytes) invade the fibrin Epithelium regenerates from the epidermis of the wound edges and grows over the newly formed fibrous tissue (regenerative phase of wound repair) completing the scar which holds the wound edges firmly together

Healing by Secondary Intention In secondary wound healing the morphological changes do not differ qualitatively from those of primary healing only quantitatively In primary wound healing only a small cleft has to be bridged but in secondary wound healing a more or less wide defect has to be filled As in primary healing the wound surface becomes covered with plasma which escapes from dilated vessels the plasma changes into fibrin and the fibrin dries and forms a scab under which the same phagocytic and proteolytic processes go on as in primary healing (destructive or lag phase of wound repair) The proteolytic ferments finally liquefy the scab which is thrown off after a few days After another few days small red granules appear each of which consists of a capillary loop covered with phagocytes and fibroblasts These granulations detach the necrotic tissue through a process of demarcation until finally the entire wound is covered with granulation tissue simultaneously epithelial cells grow from the epidermis of the wound borders over the granulations or from preserved epithelial islands thus gradually closing the wound (regenerative phase of wound repair)

Complications There are numerous local and systemic factors that can influence the normal process of wound healing such as disturbances of circulation infection disturbance of the electrolyte balance hypoproteinemia, vitamin deficiency and last but not least, stress Obviously

contamination are best treated by wound excision. Before any operative treatment is instituted, however, an examination for possible nerve, tendon, bone, and other injury should be carried out.

WOUND EXCISION AND PRIMARY SUTURE

Preoperative Preparation: Wound excision should be performed under the same aseptic precautions as any other aseptic operation. It may be done under local or general anesthesia, according to the circumstances. After the patient is undressed, the emergency dressing is removed and the wound covered with sterile gauze. The surroundings of the wound are now shaved (old blood, dirt, grease, and the like having previously been removed with benzene or ether). The direction of the shave is away from the wound, not toward it. The skin is cleansed with soap and water (Lexer, Koch, and Mason), or pHisoderm (p 4), the wound itself still remaining protected with sterile gauze The soapy solution is rinsed away with sterile water Then follows cleansing with alcohol unless pHisoderm has been used, and the operative field is now draped

Technic: The operation itself starts with the excision of the skin edges, which should be as economical as possible; a contused wound will require removal of more skin than a cut wound. Knife and forceps are now discarded and gloves changed. Then follows the excision of the lining of the entire wound tract, retractors should be inserted to open up every tract and sinus. All devitalized tissue, foreign bodies, and loose bone must be removed, the instruments being frequently changed. To expose deeper parts of the wound, longitudinal extension of the wound may be necessary by incisions. Hemorrhage is controlled by ligation of the bleeding vessels, severed tendons and nerves are sutured If the abdominal cavity is open, the peritoneum should be closed and the abdomen opened for inspection through an incision elsewhere The wound is then closed No buried sutures should be used if possible. The skin sutures should be interrupted and not too close to each other, allowing the exudate to escape, which otherwise may accumulate and interfere with primary healing An aseptic pressure dressing is applied, which eliminates dead spaces and counteracts the accumulation of exudates and hematomas and avoids stasis. In the case of an extremity, the injured part is immobilized by proper splinting or by the use of a closed circular plaster cast without padding, the limb is then elevated (For regional-wound surgery, see following chapters)

If a wound has resulted in a surface defect, the defect should be closed primarily, either (1) by mobilization of the wound edges and skin-sliding, with or without relaxation incisions (local flaps) and strictly avoid-

Control of Hemorrhage Control of hemorrhage if present, should be the first step of the emergency treatment. This as a rule can be accomplished by placing sterile gauze over the wound and using a *pressure dressing* If sterile gauze is not at hand freshly laundered linen may be used instead. If the latter is not at hand it is better to leave the wound open than to use soiled linen.

In bleeding that cannot be controlled by the pressure dressing one may apply direct digital pressure proximal to the wound upon the main artery The use of a *tourniquet* on an injured extremity particularly in cases of crush injuries should be avoided whenever possible since—according to the findings of Blalock and Duncan—the addition of local ischemia and anemia to trauma results in more deleterious effects than are caused by trauma alone But if some form of constriction is necessary the temperature and thus the metabolic processes of the distal part should if possible be lowered by artificial means (surrounding the extremity with ice) (Allen Blalock, Brooks and Duncan)

Posthemorrhage Therapy These steps consist in preventing or combating shock (p 130) relief of pain with morphine administration of antibiotics and immobilization and elevation in case of an injured extremity The patient should then be sent immediately to a place where the final treatment can be carried out.

FINAL, OR DEFINITIVE, TREATMENT

The final treatment should be carried out as soon as possible that is as soon as the patient is admitted unless he is in shock, which must be treated first (p 130) The final treatment of the wound consists of either an excision of the wound or débridement of it. Wound excision (von Bergmann Friedrich von Gaza Lexer Duval von Seemen Fuss) is permissible only within the stage of contamination while débridement—removal of retained debris as recommended by Désault and popularized by Baron Larrey during the Napoleonic Wars—is still permissible during the infected stage. Therefore wound excision and débridement are not synonymous terms (Hook)

Wounds in Stage of Contamination

The general consensus is that all wounds up to six hours after their inception—and those over six hours up to twelve hours that exhibit no definite evidence of infection—are considered to be in the stage of contamination There may be exceptions where the stage of contamination is prolonged particularly if antibiotics have been used during the emergency treatment wounds coming under treatment during the stage of

ing tension on the wound edges or (2) by means of free skin grafts or distant flaps If coverage requires a flap rather than a graft, but transfer or construction of the flap must be delayed the raw surface should be covered temporarily with a skin graft to counteract development of granulation tissue and thus possibility of infection and cicatrization

It is well known that wounds in certain regions such as the face scalp and hands heal primarily in a much higher percentage of cases than those in the inguinal and perineal regions Hence in the first class of wounds one may safely perform wound excision and primary closure after the twelfth hour· but in the second class of wounds even within the first six hours open treatment after proper wound excision followed by secondary closure is safer (see p 108) Wounds due to bites particularly human bites should not be closed primarily under any circumstances

After Treatment The after treatment of an excised and primarily sutured wound does not differ from that of any other aseptic wound except for the routine administration of antibiotics (see p 116) Sutures should be removed between the fifth and seventh days in facial wounds before the fifth day But if there is any evidence of disturbance of the primary healing process the dressing should be changed earlier and the wound inspected It is important to recognize a wound infection before complications arise The struggle between the defense system of the wound and the remaining organisms starts only a few hours after the injury A wound infection in overcoming the defense system gives rise to local and general symptoms pain redness rise of pulse and temperature and general malaise

Immediate support of the defense system by local and general measures is now paramount removal of some or all sutures spreading of the wound edges to allow exudate to escape proper drainage immobilization application of local heat—dry or moist. The infective strain of organisms should be isolated its sensitivity to all available antibiotics determined and the proper antibiotics administered in sufficient quantity Frequent blood transfusions may become necessary If in spite of all local and general support, the infection is spreading a wide incision with thorough drainage may be lifesaving· amputation in a rapidly progressing anaerobic infection may be considered (p 114)

WOUND EXCISION AND DELAYED PRIMARY CLOSURE

War wounds with the exception of wounds of the face skull hands chest abdomen and large joints as well as severe compound injuries of the extremities in civilian life should be treated by the open method

Suture Closure of the wound should be thorough Buried sutures of fine cotton or catgut may be necessary for approximation of deeper structures to avoid dead spaces Closure of the skin follows, with fine nylon or silk, preferably with an atraumatic needle Known points if present (vermilion border, nostrils, rim of eyelids) are approximated first, thus facilitating closure of complicated wounds The sutures should not be placed too close together Drainage is not necessary, except in bad compound fractures that require dependent drainage

Extensive Loss of Soft Tissue and Bone If the wound has resulted in an extensive defect of soft tissue and bone, an attempt should be made to close the surface defect with a sliding local flap (p 17) If this is impossible, the following reconstructive steps, recommended by Ivy, are indicated: (1) Arrest of hemorrhage; counteracting loss of control of tongue and thus danger to respiration by pulling the tongue forward with either a suture or a safety pin and anchoring it to the dressing, débridement of the wound and wound excision if necessary, fixation of bone fragments in approximately normal position by wires or other extra-oral appliances; adjustment of torn tissue flaps, dependent drainage, and systemic administration of antibiotics. (2) Final reduction and fixation of the fragments of the mandible by special splints (such as those made of acrylic resin), affording a clear view of the underlying teeth and gum tissue and providing feeding space. (3) After all wounds look clean and healthy, transplanting a flap to cover the soft-tissue defect (4) Three months later, replacement of the bone defect with a bone graft unless there has been infection, in which case one ought to wait six months before transplanting bone, and to provide preoperative and postoperative antibiotic therapy (5) Provision of artificial dentures to replace lost teeth

Wounds of Hand: For wounds of the hand, see p 683

Wounds of Joints: Scott's vast experience with joint injuries of the British Armed Forces of World War II confirmed the teaching of Bartos and Mazo that the period of time within which surgical cleansing of a joint wound is possible is longer than for other wounds It seems that wounds of synovial membrane and articular cartilage are more resistant to infection than any other wound, consequently, the joint capsule can be closed primarily after proper cleansing of the joint spaces even a long interval after wounding and in the presence of gross contamination The periarticular tissue and skin can also be closed loosely if the patient is treated within a few hours of the injury Otherwise, it is left open and closed secondarily after a few days (p 108), although the joint capsule is always closed primarily The limb is immobilized in a plaster

the length of time is the governing factor as Fisher has aptly pointed out with minimum to moderate drainage and healthy looking pink granulations If this is the case delayed primary suture should be under taken If it is possible to approximate the wound edges without much mobilization and tension the wound margins are excised together with all granulation tissue and the wound sutured loosely with interrupted stitches If tension is expected or one is in doubt, it is wiser to use a split skin graft to cover the granulating area Thus the immediate purpose of closure of the raw area and control of infection is achieved If the area requires more stable tissue a graft replacement with a pedicled flap may be considered later on Immobilization is maintained and antibiotic treatment carried out for at least another ten days

REGIONAL WOUND SURGERY

Maxillofacial Wounds. Wounds of the face require special considera tion In dealing with facial injuries one must realize that the ultimate outcome depends much upon the initial repair Except for patients having evidence of cerebral injuries most thorough repair of the wounds should be performed to obtain a minimum of deformity and disfigure ment An accurate preoperative evaluation of the extent of the injury is of course, necessary This may include neurological and x ray examina tions. The local treatment starts with preoperative cleansing which should be performed with soap and water Dirt-stained or oil impreg nated wounds should be thoroughly cleansed It is quite easy to remove foreign bodies at this time but it may be difficult or impossible after healing has taken place Since infections are rare in the face and gas gangrene almost unknown the majority of the wounds can be closed primarily even if seen from eighteen to twenty hours after the accident, unless they are badly contused and soiled The excision of the wound should be as economical as possible After change of instruments inspec- tion should follow for damage to deeper tissues such as muscles and nerves A divided Stensen s duct should not be overlooked It is relatively easy to suture it at this time with an end to-end suture over a dowel (see p 166) Later on repair work is difficult.

Fixation Facial fractures should be treated at this stage. Fixation of fractured jaws is aimed at the restoration of normal occlusion of teeth and the function of mastication The jaws may be temporarily immobil ized by bandaging and interdental wiring Such appliances if needed and not available immediately can be applied later on a few hours after the wound is sutured (Chpt XII) Depressed fractures, such as of the nose orbit and zygoma should be elevated.

must then be excised, as well as the granulations, and the wound edges sutured together Since this is not often possible without much undermining and tension, it is advisable to cover the granulations with a split skin graft, which, after healing has taken place, can be replaced by more stable tissue, such as provided by skin-sliding or a rotation flap or flaps from distant parts.

Wounds in Stage of Infection

General Considerations: Generally speaking, a traumatic wound is considered contaminated during the first six hours, becoming infected during the following six hours, and being infected after twelve hours If, however, antibiotics have been used during the first six hours, the stage of contamination may be prolonged to twenty-four hours and longer But, ordinarily, any wound coming under treatment twelve hours after injury should be considered infected, and should not be excised At that time, the defense mechanism of the wound is being built up against the organisms that have adapted themselves to the new surroundings and become invasive Hence, any extensive operative procedure would break down rather than support the defense of the wound.

Procedure Débridement in the original sense of the word (Désault, Larrey)—that is, removal of retained débris—may be safely carried out, but any procedure resulting in breaking down the defense mechanism, as wound excision would do, should be avoided The wound is gently spread, retained debris is removed, and a piece of gauze (plain or petrolatum) is inserted to the depth of the wound However, if there is evidence of deep infection, incision for free drainage, with removal of dead tissue, should be carried out The next step consists in supporting local defense by promoting hyperemia and exudation—immobilization and elevation of the extremity, application of local heat, moist or dry, and administration of antibiotics

The first dressing of the wound may remain in place for several days, if the wound looks clean and free of infection, delayed primary suture can be carried out (p 108) Where there had been actual infection, however, but the infection remains controlled, promotion of granulations and demarcation and elimination of necrotic tissue should be the policy of further treatment, this may be achieved by local and general measures. Dakin's solution is beneficial if necrotizing processes are present, scarlet red and mercury ointments stimulate formation of granulations, crystal sugar (need not be sterile) sprinkled over the wound and covered with petrolatum gauze promotes exudation owing to its hygroscopic properties;

cast and antibiotics are administered The synovial membrane however acts as a barrier to the transmission of drugs from the bloodstream Hence it is advisable to introduce penicillin (about 100 000 units in 8 cc of sterile water) into the joint after closure A window is then cut into the cast. If the joint swells postoperatively it should be aspirated as often as necessary and after each aspiration penicillin is introduced If the joint becomes actually infected aspiration must be replaced by drainage.

Wounds of Bones. Since the advent of antibiotics treatment of open fractures is aimed at closure of the skin wound at the earliest time compatible with safety either by primary or delayed primary suture or by secondary suture A certain standardization has thus evolved based on the vast experience of such authorities on the subject as Watson Jones Böhler Key Magnuson and Stack, Furlong and others

The general principles of the treatment can merely be summarized here Under general anesthesia cleansing of the involved region is similar to the method described on p 4 The majority of surgeons prefer to operate without the aid of tourniquet. The wound is excised and débrided with minimal sacrifice of viable tissue The displaced fragments are reduced as accurately as possible by traction and manipulation Internal fixation if not vitally needed should not be used A substitute for internal fixation can be provided by two Steinmann pins one through the proximal and one through the distal fragment away from the wound as recommended by Moore They are incorporated in the cast.

The wound is sutured with interrupted sutures if the patient is treated within the first ten to twelve hours after the injury If however there is much destruction and crushing of the soft tissues the wound is left open In war injuries the wound is always left open If primary suture is precluded by loss of surface tissue, a split skin graft should be applied as a temporary measure at this stage flaps however should not be rotated at this time The wound is covered with petrolatum gauze and a pressure dressing applied followed by application of a plaster cast with immobilization of the joints above and below the fracture the limb is elevated and antibiotic treatment administered

In wounds that have been left open delayed primary suture or in the case of a surface defect split skin-grafting is performed between five and ten days later as outlined on page 108 unless infection has intervened These procedures can be carried out through a large window in the cast. Wounds that have been left open and cannot for any reason be practicably closed by delayed primary suture may be permitted to heal by granulation and closed at the earliest time possible. The wound edges

GAS GANGRENE

Clostridium welchii, together with a great variety of other anaerobic gas-producing clostridii, is the common cause of clostridial myositis, or gas gangrene The characteristic clinical signs are pain, swelling, crepitation of the tissues surrounding the wound, a dry appearance of the wound, a thin, brown, watery, foul-smelling discharge, moderate fever, high pulse rate, low blood pressure, and evidence of toxemia Serial roentgenograms, for evidence of gas in the soft tissues, may be of diagnostic value

As far as treatment is concerned, nothing short of surgery can save the patient's life Altemeier summarizes the treatment as follows Radical surgery is required as soon after diagnosis as possible The operation embraces multiple incision for decompression and drainage of the fascial compartments, excision of the involved muscles, or open amputation, if necessary, followed by adequate immobilization of the affected part Polyvalent gas-gangrene antitoxin is administered before and after surgery—50,000 units every four to six hours, as indicated, to aid in the control of the toxemia Penicillin is injected in very large doses, up to 1,000,000 or more units, every three hours before and after surgery to aid in the control of the infection After its obvious control, the dose of penicillin may be gradually reduced Other antibiotics should also be administered Streptomycin or terramycin may be given in daily intravenous doses of 2 gm Topical use of zinc peroxide ointment on wound surfaces after radical surgery is recommended

SUPPORTIVE THERAPY

In patients with extensive, complicating, infected wounds, general supportive measures are of great value for stimulating local and general health, such as correcting secondary anemia, hypoproteinemia, or any vitamin deficiency, particularly of vitamin C Hypoproteinemia results in retarded fibroplastic proliferation and delay of wound-healing (Thompson, Ravdin, Rhoads and Frank, Rhoads, Koster, and Kasman, Co Tui) This should be counteracted by transfusions of blood and plasma and a high protein diet (see p 136) Vitamin C is essential to wound-healing (Arey, Lanman and Ingalls, Hartzell, Winfield and Irvin, Hartzell and Crowley, Bartlett, Jones, and Ryan) Deficiency of vitamin C results in failure of conversion of the precollagen substance of the scar to collagen Moreover, the proliferating connective-tissue cells remain in a state of immaturity These two factors may delay the healing process of a traumatic wound Daily doses of from 200 to 300 mg of ascorbic acid (and even more) are normally given Administration of iron and exposure to ultraviolet light are also valuable

balsam of Peru is an excellent deodorant cod liver oil owing to its bactericidal properties and its vitamin content is highly recommended to promote early liquefaction of dead tissue and to stimulate granulation and epithelization The value of ACTH or cortisone (Alrich et al Baxter et al [see also p 127]) in promoting wound healing has remained doubtful Closure of the wound with skin-sliding, grafts or flaps should be carried out at the earliest time compatible with safety

TETANUS

Tetanus also called lockjaw or trismus is caused by the anaerobic Clostridium tetani its toxin acts upon the neuromuscular end-organs causing spasm and rigidity of the voluntary muscles In mild cases only a local rigidity of a single muscle group near the wound is present. In the generalized form a typical clinical picture develops characterized by trismus stiffness of the jaw and risus sardonicus soon followed by painful clonic spasm of the spinal group of muscles precipitated by external stimuli. The incidence of the disease has diminished since introduction of immunological methods

Treatment Prophylaxis by active immunization with tetanus toxoid has apparently greatly diminished tetanus Those having had active immunization should have a booster dose of 1 cc. of toxoid in case of wounding In all patients without a history of active immunization in whom the wound has been caused under circumstances that may have introduced the tetanus bacillus a prophylactic dose of tetanus antitoxin (3000 international units) should be injected after preliminary skin testing for sensitivity to horse serum The dose should be repeated after seven days if the possibility of tetanus is great.

Early excision and débridement of the wound is however the most important prophylactic step Should infection become established the only hope of cure lies in early diagnosis and prompt treatment. The latter consists mainly in heavy sedation with barbiturates or paraldehyde or continuous infusion of a dilute solution of pentothal sodium wide excision of the wound 100 000 international units of tetanus antitoxin injected intravenously after preliminary testing for sensitivity to horse serum daily repetition of smaller doses (20 000 units) and infiltration of the wounded region with 10 000 units before excision of the wound If the skin test is positive rapid desensitization should be carried out to permit injection of a therapeutic dose. Antibiotic treatment is of no value in combating the tetanus bacillus itself but may be useful in checking secondary infections.

At this time, the N'-heterocyclic derivatives of sulfanilamide, the *sulfapyrimidines* (sulfadiazine, sulfamerazine, and sulfamethazine) are generally recognized as the most satisfactory of the sulfonamides for the treatment of susceptible systemic infections, especially when combined as triple sulfonamides The combination has the virtue of superior antibacterial efficacy and relatively low toxicity In addition, such compounds as *sulfisoxazole* and *sulfadimetine* and others, because of their increased solubility in urine and relatively higher concentration, are primarily reserved for the treatment of urinary-tract infections Likewise, as a result of their poor absorption from the gastrointestinal tract, *phthalylsulfathiazole* and *succinylsulfathiazole* are employed in infections of the gastrointestinal tract In general, there is little qualitative difference in the antimicrobic spectrum of the various commonly employed sulfonamides The most susceptible types of organisms include streptococci, staphylococci, pneumococci, gonococci, meningococci, Escherichia coli, and Haemophilus influenzae The sulfonamides may be employed alone, or as mixtures or in combination with the antibiotics

Other synthetic antimicrobial agents included in this group are two drugs, *para-aminosalicylic acid* and *isoniazid,* which find their greatest usefulness as adjuncts in the treatment of tuberculosis In addition, *nitrofurantoin* is employed in urinary-tract infections

Antibiotic Agents: Since the observations of Pasteur and Joubert in 1877, it has been known that certain microorganisms are capable of inhibiting the growth of other microorganisms, a phenomenon that is called "microbial antagonism" The inhibiting action of one organism upon another has been shown to be due to the production of certain metabolic antibacterial products on the part of the antagonistic agent

Penicillin, discovered by Fleming in 1929 and systematically investigated in 1940 by Chain, Florey, and co-workers, was shown to be such an agent and, although many other antibiotics have been introduced since that time, penicillin still remains the sheet anchor of antimicrobial therapy Unlike the sulfonamides, penicillin is effective in the presence of pus and, with certain questionable exceptions, no organisms have been shown to develop a significant degree of resistance to penicillin during its administration The organisms most susceptible to penicillin include pneumococci, streptococci, staphylococci, certain of the clostridia, and strains of lactobacillus In addition, the gram-negative cocci, meningococci, and gonococci are sensitive to this drug Treponemal and borrelial infections can also be successfully treated with penicillin

Streptomycin was introduced for clinical use in 1944 by Waksman In contrast to penicillin, it possesses antibacterial activity against both gram-

ANTIMICROBIAL THERAPY

By Harrison F Flippin M D

Although modern antimicrobial therapy had its beginning less than a century ago with the bacteriological discoveries of Pasteur and Koch and the prophylactic use of chemical agents for septic wounds by Lister it was the clinical application of chemotherapeutic substances by Ehrlich that opened the gates leading to the present status of antimicrobial agents It was Ehrlich who conceived of an antimicrobial agent as one capable of destroying the offending agent within the tissues of the body and yet of sufficiently low toxicity not to harm the host Likewise he emphasized that certain organisms could acquire resistance to antimicrobial agents and that the resistance of some organisms was an inherent characteristic. Although Ehrlich s dream of an ideal antimicrobial agent has as yet not been fully realized the results that are now being obtained with these agents in the treatment and prevention of many types of infections probably surpass Ehrlich s most optimistic expectations This has been brought about largely as a result of two outstanding developments (1) the synthetic antimicrobial agents such as the sulfonamides, para-aminosalicylic acid isoniazid and nitrofurantoin and (2) those products that are biosynthesized by microorganisms, the antibiotic agents

Certainly these anti infective agents have completely revolutionized the practice of medicine but with mixed results The conquest in the control of infections may be considered a wonderful triumph but at the same time one must not forget that this triumph has been tinged with tragedy in that certain undesirable consequences often follow the use of these agents

Sulfonamides Shortly after the introduction of prontosil by Domagk in 1935 and sulfanilamide the reduced form of prontosil (Trefonel et al Colebrook et al) and its allied compounds certain shortcomings became apparent (1) Many strains of bacteria are naturally resistant to their action (2) Initially susceptible strains in a species can and do develop resistance to the sulfonamide drugs during treatment, so that a number of bacterial infections are no longer amenable to sulfonamide therapy (3) These drugs may produce a variety of serious untoward reactions. (4) The antibacterial activity of the sulfonamides is diminished in the presence of pus Because of these disadvantages and with the introduction of the antibiotics, indications for the sulfonamides became greatly restricted Nevertheless, within the past several years there has been a renewed interest in their use largely as a result of the toxic reactions associated with the antibiotics.

preparation for intestinal surgery and as a topical medicament for pyogenic skin infections. When administered systemically, neomycin may cause slight to severe deafness, as well as transient renal irritation. In selected cases, however, especially in proteus and pseudomonas infections, it may be administered intramuscularly for short periods of time.

Complications of Antimicrobial Therapy. When using the antimicrobial agents, one has to keep in mind the possibility of toxic reactions, the chances of sensitivity, their effect on the bacterial flora of the patient, and their effect on the patient with regard to resistance to further infections.

For the most part, toxicity is due to the chemical nature of the drug, and the severity of the reaction is in proportion to its dosage. Such reactions may occur locally or systemically. Likewise, sensitivity reactions may result from contact with the drug or may represent a generalized allergic reaction. In addition, there are various other reactions described, such as the oral and gastrointestinal manifestations following the administration of the broad-spectrum antibiotics. The mechanism of these is not well understood, but it appears that the resulting changes in the intestinal flora may bring about a deficiency in certain vitamins. Likewise, the suppression of the normal bacterial growth in the intestinal tract may lead to secondary infections, which in most cases are not serious, but at times prove severe and occasionally end fatally. Admittedly, most of the toxic reactions are relatively uncommon in proportion to the widespread use of these agents and most are temporary, but serious damage and even fatal results are common enough to justify an earnest plea for caution against the indiscriminate use of these drugs.

In addition, the use of these agents may accelerate the emergence of resistant strains of bacteria among certain species. In this connection, infections acquired in hospitals represent a serious problem, and if the situation is not resolved, such infections may become much more important to us in the future.

Certainly, the antimicrobial agents have become valuable adjuncts in the practice of surgery, but it is to be remembered that regardless of their proved therapeutic and prophylactic effectiveness, they are not to be used to the exclusion or neglect of other proved forms of therapy, such as good surgical technic. Furthermore, in view of the potential hazards associated with these drugs, their use should be reserved primarily for established infections in which the causative agent is known to be sensitive to their action. It therefore behooves the surgeon to reexamine the circumstances in which these agents are employed before, during, or after operation.

positive and gram negative organisms and is of particular importance against the tubercle bacillus By virtue of its antituberculous properties streptomycin remains a uniquely valuable drug and should, for the most part be reserved for the treatment of tuberculosis However strepto-mycin is still employed in selected cases either alone or in combination with other antimicrobial agents

The Broad-Spectrum Antibiotics. The expression broad-spectrum is used to designate certain antibiotics that possess activity against a great variety of microorganisms in contrast to antibiotics such as penicillin with a narrow spectrum of activity Experience has indicated that the wider the spectrum of activity of an antimicrobial substance the greater is the toxicity and the specificity of action is lessened Fortunately the now available broad-spectrum antibiotics are of sufficiently low toxicity to permit their administration in man and are effective in infections caused by bacteria rickettsiae and certain viruses Because of their pharmacological properties the broad-spectrum antibiotics unlike strep-tomycin can be administered successfully by mouth

Chloramphenicol, the first of these broad spectrum antibiotics, has found its chief usefulness against organisms of the Salmonella group especially typhoid fever Because of the possibility of the development of blood dyscrasias in patients in whom it is employed it is not recom mended for general use However it remains a valuable therapeutic agent in selected cases.

The *tetracycline* group of antibiotics is composed of chlortetracycline oxytetracycline and tetracycline In general there appears to be little difference as far as therapeutic effectiveness is concerned between the three members of this group although some differences may exist.

Erythromycin is considered a member of the broad-spectrum group although its greatest usefulness is in the treatment of *infections* due to staphylococci streptococci pneumococci and organisms resistant to penicillin

Although *polymyxin B sulfate* is an agent of considerable toxicity its unique effectiveness in infections due to Pseudomonas aeruginosa has justified its introduction into clinical practice. This agent should be em ployed parenterally only in hospitalized patients since careful observa tion for renal damage is essential to its safe use

Because the parenteral administration of *bacitracin* is often followed by kidney damage and only a small amount is absorbed when given by mouth this drug finds its chief usefulness as a topical or oral medicament.

Since *neomycin* is not absorbed into the bloodstream from the gastro-intestinal tract or skin it has found its *chief* usefulness in preoperative

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It would lead far beyond the scope of this book to go into the fascinating history of this subject and the details of antibiotic therapy The reader is referred to recent excellent monographs such as those by Flippin Pulaski Colebrook Meleney Finland Hussar et al and others

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IV

TREATMENT IN MAJOR AND MINOR BURNS

THE treatment of burns has undergone significant changes during the past decades Up to 1900, the treatment of burns was more or less local Although laboratory studies were made and the significance of fluid loss and hemoconcentration (Baraduc, Tappeiner) and changes in the morphology of the blood (Wertheim, Lesser) were known, these important facts were, as a rule, not followed up therapeutically It is estimated that two thirds of the patients who were burned died from shock and infection

Historical Phases in Treatment. In the beginning of our century, general treatment started to receive more consideration, and was under the influence of the toxin theory. According to the latter, toxic substances are released from the burned area, causing shock and toxemia (Bardeen, Wilms, Pfeiffer, Dale and associates, Cannon and Bayliss, Robertson and Boyd) The toxin theory lost importance since Underhill and his associates systematically investigated the role of fluid loss in burns (1921–1923). Since that time, treatment has gone through four significant phases Each phase has added a definite improvement, with a lowering of the mortality rate and the lessening of suffering of the patient

Theory of Hemoconcentration as Cause of Toxemia In 1921, Underhill and his coworkers had the opportunity of treating twenty-one persons seriously burned in a theater fire in New Haven At the same time, they made important investigations of fluid loss and blood concentration following burns Their investigations led them to the conclusion that the clinical picture of toxemia developing in cases of burns is not due to absorption of a toxic substance derived from burned areas, but due to

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plasma Weiner, Rowlette, and Elman were among the first to stress the importance of replacing the lost plasma by plasma infusions, they also reintroduced the intravenous use of gum acacia, owing to its colloidal properties

Elkinton, Wolff, and Lee, Cope and coworkers, Hegemann, and others state that the capillary permeability with continued shift of plasma and its proteins to the extravascular spaces in burns lasts from thirty-one to forty hours During this period, excessive hemoconcentration may be prevented by small, repeated transfusions of plasma or plasma expanders After the capillaries have regained their impermeability to protein, the deficit of plasma protein may be corrected quantitatively by a large transfusion of plasma or plasma expander

Role of Red Cells. Until recent years, plasma alone has been considered the proper colloid to replace the loss Whole-blood transfusions have been considered harmful, since they might increase the cellular constituents of the blood with its high cell concentration However, it has been recently demonstrated by Colebrook and associates, Cope, Moore, and associates, Evans and Bigger, Raker and Rovit, Brooks and Dragstedt, and Kerr that a thermal burn causes a destruction of a rather large amount of red cells, which is followed by anemia, the latter has long been observed to follow several days after the trauma How large the loss of the red cells is cannot be estimated by determination of the hemoglobin or the hematocrit But it indicates that massive whole-blood transfusions are needed to replace the cellular loss

Role of Sodium and Potassium Another recent addition to our knowledge of the burn problem is the severe sodium deficiency, which in itself may aid in the production of shock (Cope and Moore, Roberts, Fitts, Ravdin, Rhoads, Evans, Blocker, and others) Associated with the rapid drop in serum sodium, there is a period of sodium retention, usually lasting several days Following the period of retention, the kidneys as a rule excrete large amounts of fluid and sodium Hence, contrary to the previous consensus, it is now believed that large quantities of sodium should be given in the early phase of the burn treatment Intravenous administration seems to be preferred, although the oral route is also said to be effective, and has the advantage of ease of administration (Blocker et al) The role that potassium plays in shock is not well understood A certain degree of potassium depletion seems to occur, but rather in the terminal stages than in the beginning of shock, and since renal control of potassium is not so exacting as that of sodium, losses may continue in the face of severe deficit and require special replacement of this ion

hemoconcentration The blood capillaries become injured from the heat and become permeable, thus results in a rapid pouring out of fluid on the burned surface and into the tissues causing marked general edema of the affected part The rapid and continued loss of fluid from the blood in cases of burns quickly induces a marked concentration of the blood The condition of the patient depends on the amount of the concentration. Underhill considered restoration of normal concentration of prime significance. His systematic treatment of burns consisted simply in the forcing of fluid by mouth rectum hypodermoclysis or intravenous infusion Thus for the first time the important fact of fluid loss and hemoconcentration although known before was systematically followed therapeutically and the dynamic phase of fluid and electrolyte therapy was entered not only in the treatment of burns but also in other fields of surgery (Crile Walters Coller and Madock Lockwood and Randall and others)

Role of Plasma Remarkable as the recognition was that hemoconcentration or hypovolemia (i e. disproportion between circulating volume and the capacity of the vascular system) was the major factor in causing burn shock and toxemia the recommended treatment did not hold what it had promised, since the escaping fluid was not merely water Tappeiner (1881) pointed out that death from burns was due to hemoconcentration from loss of plasma and he was one of the first to advise the infusion of serous fluids Later on Bayliss for the same reason recommended intravenous use of 6 per cent gum acacia It was not however until much later that their advice was appreciated and this came about mainly through the investigations of Blalock McIver McClure Harkins Elman Scudder Moon Lee Elkinton Wolff Rhoads Black Hecht and Weese and Schultz. A fine collective review of this subject has been recently published by Ravdin and Ravdin.

Normally fluid is kept from leaking disproportionally through the capillaries by the colloid osmotic pressure of the plasma proteins in differential concentrations on either side of the semipermeable capillary membrane If as in burns the capillaries become injured and permeable plasma or a fluid closely corresponding to plasma escapes from the circulation in abnormal amounts the osmotic pressure is reduced within the capillaries If in such a state aqueous solutions are injected as in Underhill's treatment the plasma proteins become diluted to a concentration that makes it impossible to hold the fluid given either intravenously or by other means into the bloodstream In other words in severe burns the more that aqueous solutions are administered the more that fluid is poured out. What is needed is the replacement of the lost

ACTH and cortisone in the treatment of severe burns, thus supporting the defense system of the body (Rehn and Whitelow, Adams and associates, and others).

This subject, however, is quite controversial, since deleterious effects have been reported after such treatment (Evans and Butterfield, Derber, and Hegemann). It is also theoretically conceivable that under severe shock the pituitary and adrenal glands are in a condition of maximal stress, further stimulation may be compared to whipping a tired horse, thus inviting rather than preventing a breakdown. On the other hand, it must be admitted that the adrenal response may not be maximal and further adrenal stimulation might be crucial in helping the patient over the critical period. At present, we have no way of evaluating the adrenal cortical reserves. Hence, if strengthening of the hormonal defense is considered replacement therapy with hydrocortisone is safer than whipping with ACTH. Further studies on eosinopenia after secretion of corticotropin (Rud) may become helpful in estimating the strength of the hormonal defense system. All hormones have definitely proved to be ineffective in reducing the abnormal capillary permeability in recent burns (Cope, Raker). More successful treatment is to be expected when more is known of the hormonal basis of shock. In this respect Hardy's recent publication is enlightening.

Classification of Burns: Thermal burns are usually classified according to penetration. The *first-degree* burn, combustio erythematosa, is characterized by erythema of the skin from enlargement of the dermal vessels due to paralysis of their nerves. The *second-degree* burn, combustio bullosa, is characterized by formation of blisters between the epidermis and the corium. In *third-degree* burns, combustio escharotica, the entire epidermis is destroyed. The eschar is hard and insensitive, brownish or black, the vessels are thrombosed, and the surrounding parts exhibit burns of first and second degree.

Clinical Picture: The clinical picture of a burn depends mainly upon the extent of the involved area. Minor burns cause only local reaction, extensive burns, however, cause general reaction, which may run through the following stages: primary shock, secondary shock, acute toxemia, septic toxemia, healing, or death.

Shock. Shock, in general, is divided into primary and secondary shock. *Primary* shock is the collapse that follows the trauma immediately, and is probably due to pain and to various other reflexes and psychological factors; it is usually not of serious consequence. *Secondary*, or traumatic or hypovolemic, shock is the circulatory collapse that follows one hour after the injury, and is characterized by pallor, cyanosis of lips,

Role of Hormonal Defense The role of the adrenal cortex in traumatic shock has increasingly become the focus of attention Swingle and coworkers Heuer Andrews and others showed that adrenal ablation led to shock this was subsequently found to be due largely to salt depletion Intravenous administration of adrenal cortical extract was recommended but the results were questionable and sometimes even harmful Further research however culminated in Hans J Selye s startling theory and concept of how stress causes disease through the general adaptation syndrome an expression of adrenocortical activity in response to a wide variety of pathological states

Selye derived his concept from animal experiments. When an animal was subjected to stress there was an alarm reaction i e a quick response of the body to the attack by a nervous defense which had long been known to physiologists and by an even more important hormonal defense which was recognized by Selye According to his theory the pituitary gland pours out hormones which in turn stimulate the adrenal glands to pour out others and thus adapt the body to all kinds of stress If the stresses continued the alarm reaction was followed by a period of adaptation adaptation syndrome during which the animal learned to live with its stress If the strain continued or the defenses were inadequate the stage of exhaustion was reached with reappearance of signs of the alarm reaction ending finally in death Autopsy showed a striking variety of pathological changes which looked like those in human victims of heart and circulatory disorders arthritis kidney damage and other conditions Evidently the breakdown was caused by excessive production of hormones by the pituitary and adrenal glands as an emergency defense against stress After intensive research Selye found the somatotropic hormone (STH) of the pituitary and desoxycorticosterone (DCA) of the adrenal cortex responsible for it. It became obvious that if STH and DCA could produce a host of diseases there must be a mechanism to control them or other hormones to neutralize them since otherwise the resulting pathological changes would be common Thus Selye s work foreshadowed the discovery of ACTH and cortisone

The general consensus is now that the combat mechanism of the body goes into action in response to assault—in burns for example—and is initiated by the pituitary which increases the output of ACTH the adrenocorticotropic hormone of the hypophysis which in turn stimulates the adrenal cortex to increased secretion of some 25 corticosteroids Of the latter cortisone (compound E) and hydrocortisone (compound F) are considered the principal hormones basically needed in the defense against injuries that threaten life Hence it seems inviting to administer

IMMEDIATE TREATMENT

Management of Burn Shock: Almost every patient with extensive burns exhibits more or less evidence of shock, which must be treated before proceeding with local treatment. Everything must be done to

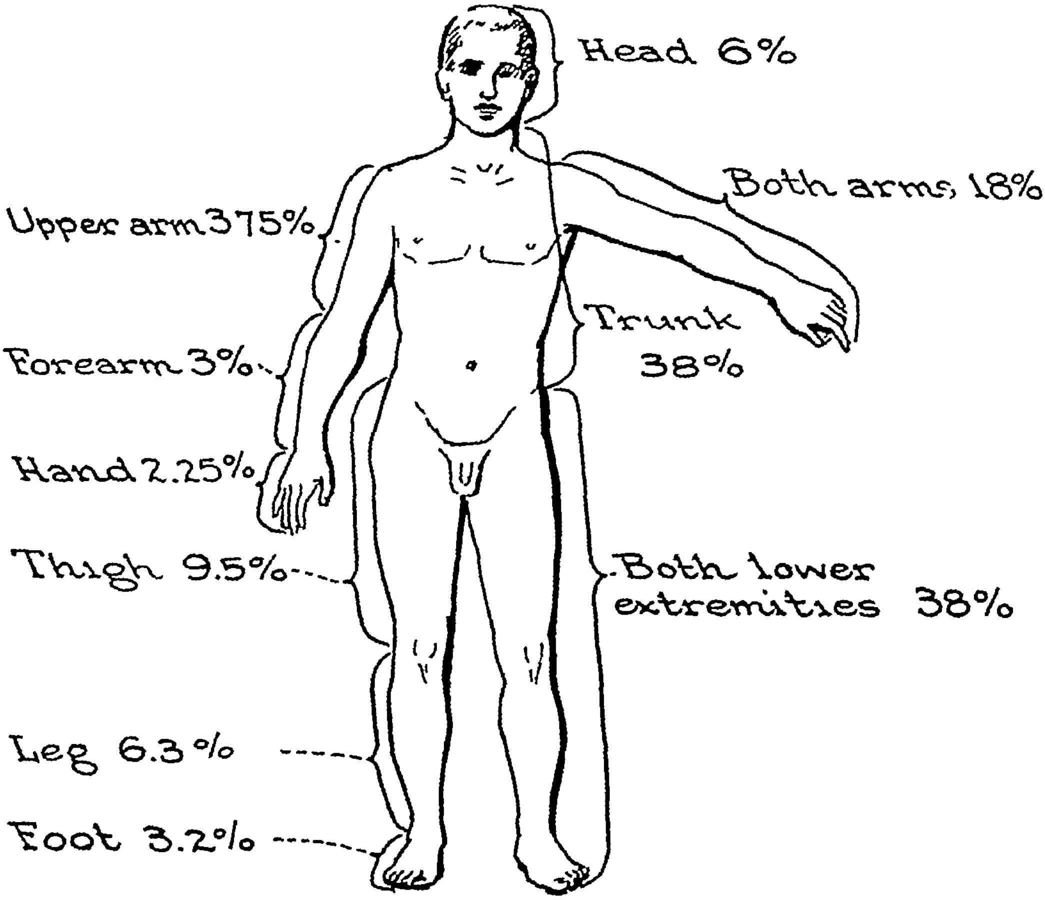

Fig 50 Estimation of body surface expressed in percentage (Berkow) Figures include front and back

combat shock, and everything must be avoided that would increase it Pain is relieved with morphine or demerol intravenously (one half to two thirds of the subcutaneous dose) The clothes are removed with the least disturbance to the patient It is now imperative to estimate and chart the extent of the burned area and the patient's weight The extent of the burned area is estimated according to Berkow (Fig 50) or Wallace According to the latter's rule of nine, head-neck is estimated at 9 per cent, each arm, 9 per cent, anterior trunk, 18 per cent, posterior trunk, 18 per cent, each leg, 18 per cent, genitalia, 1 per cent The time that has elapsed since the onset of the burn is recorded The burned area is wrapped in sterile sheets, the foot of the bed or stretcher is elevated, and the patient is wrapped in blankets and kept comfortably warm without

cheeks and extremities cold moist, sweaty skin rapid, shallow respiration poor pulse volume, collapsed peripheral veins restlessness nausea vomiting falling blood pressure, subnormal temperature increased hematocrit readings and leukocytosis In burns as in other traumatic cases primary and secondary shock may merge imperceptibly

Toxemia The well known syndrome of toxemia follows extensive burns within the first three or four days if the patient survives the secondary shock. There is no agreement on the nature of toxemia The fact that it can occur or persist after the capillaries have regained their impermeability would exclude hemoconcentration as the sole cause absorption of toxic substances and infection may also play a role Vomiting is the first evidence of beginning toxemia It is soon followed by a typical syndrome that is characterized by mental and physical disturbances The patient becomes restless complains of thirst and pain and at times is delirious he is unable to retain food temperature rises and remains high and the condition soon assumes a septic character Pulse and respiration are fast. The tongue is dry the blood pressure may remain normal Leukocytes are markedly increased (25 000 and more) The urine is scanty and concentrated albumin and acetone may appear Hemoconcentration with a rapid increase in the hematocrit readings although present early may reach its peak at the onset of the toxic stage Blood chlorides and plasma proteins are reduced blood sugar and nitrogen elevated This picture of toxemia may last from one to two weeks Then if the patient survives his mental and most of his physical disturbances clear up However there may remain an elevated temperature and pulse marked leukocytosis and evidence of secondary anemia and hyproteinemia until the greater part of the raw surfaces has healed

Infection as already mentioned, is partly responsible for the toxemia syndrome But toxemia may recur later days or weeks after the symptoms of acute toxemia have disappeared. The symptoms and findings of the septic toxemia (Wilson) resemble those of any other surgical septicemia. The prognosis is grave fatal signs are apathy and semiconsciousness Blood pressure drops the pulse becomes thready and the respiration accelerated and shallow· vomiting diarrhea clonicity coma collapse and a marked rise in temperature precede the fatal issue

Treatment of Extensive Burns

The treatment of extensive burns can be divided into immediate and late treatment. The *immediate* treatment consists in combating shock toxemia and infection The *late* treatment consists in combating mal nutrition covering the raw surfaces with skin grafts and rehabilitation

expanders, chiefly dextron, have been found as effective and safe as pooled plasma. This subject has been critically reviewed by Gropper et al and Ravdin Evans, whose formula has been widely adopted here and abroad (Hegemann, Allgower, etc), determines the quantity of colloid solutions to be given during the first twenty-four hours (from time of burn, not from time of fluid start) by multiplying the patient's weight in kilograms by the percentage of body surface involved in second- and third-degree burns One word of warning is in order not to overestimate the area, to overestimate is the tendency An amount of isotonic salt solution equal to that of colloid is also given and, in addition, 2000 cc of 5 per cent glucose in water to insure a good urinary output Hence, a 70-kg man with a 35 per cent body-surface burn would require 2450 cc of colloids, 2450 cc of 0 9 per cent sodium chloride, and 2000 cc of 5 per cent glucose in water in the first twenty-four hours Half of this amount is given within the first eight hours and the remainder within the next sixteen hours. For the second twenty-four hours, only one half of the colloid and salt solution of the first twenty-four-hour period is administered, plus 2000 cc of glucose in water

This formula, however, should not be followed blindly In extensive burns, for example, in which the hemoglobin level is more than 19 Gm per 100 cc and the urinary output low, more whole blood than plasma is needed, the required colloid solution should then be made up of two parts of whole blood to one of plasma Otherwise, equal parts of whole blood or plasma or plasma expanders* are required Less than the estimated amount of fluid should be given to children, older people, those having respiratory-tract burns, and those with over 40 per cent body-surface burns, to prevent pulmonary edema Each patient must be closely watched The urinary output and hemoglobin and hematocrit determinations serve as important guides, but are not the only ones in fluid therapy, since they can mislead For instance, the hematocrit level may remain normal throughout the shock phase if cells and plasma are lost at the same rate

Clinical signs and symptoms, such as thirst, rapid pulse, reduced pulse volume, cold extremities, and collapsed veins, have at least as much value as laboratory findings In general, after the first forty-eight hours, if a good urinary output and a hemoglobin level below 19 Gm are maintained, it is no longer necessary to administer intravenous colloid and salt, since by that time every patient takes adequate amounts of fluid

* Coworkers of the late Dr Evans (Haynes, Martin, Purnell) recently came to the conclusion that if dextron is used as a plasma expander, much less whole blood is needed They estimated that in children the ratio between blood and dextron is 1 1½ and in adults 1 2

overheating Inhalation of oxygen may be of value particularly in respiratory tract burns The latter must be recognized early so that fluid and electrolyte administration is limited to the minimal effective amounts to prevent pulmonary edema The patient is observed for any physical sign of shock. Thirst is often an outstanding sign also quickening of the pulse and reduced pulse volume, cold extremities and collapsed veins.

Restoration of Fluids While the foregoing procedures and observations are carried out the most important measure to combat shock is undertaken the replacement of fluid losses and the restoration of blood volume by continuous intravenous infusion of large quantities of colloids (including blood) and electrolyte solution. From studies of well-conducted burn clinics * it is now possible to relate the extent of the burned surface to the volume of fluid loss which is proportionate The volume of fluid infused intravenously must correspond to the patient's requirements There are many formulas suggested as guides for the administration of proper amounts of fluids during the shock phase. Of these the formula of Evans is widely used. He emphasizes that the hourly urinary output is one of the most important guides to proper fluid and salt therapy although it is limited by insensible and in burns highly variable loss of fluid from lungs normal skin and burned surfaces (Hardy et al) Insertion of an indwelling catheter in the urinary bladder is advised the bladder is emptied and the hourly urinary output is from then on recorded. Next a small polyethylene tube is inserted in one of the ankle veins or in any other available vein to provide blood samples for typing cross-matching and hemoglobin and hematocrit estimations the latter two determinations should be repeated every six hours for the first forty eight hours In extensive burns a suitable colloid solution (plasma plasma expander whole blood) and electrolyte solutions are given at once and administered rapidly enough to secure a urinary output of from 25 to 50 cc. during the first hour When the burn is extensive—in children 15 to 20 per cent of the body surface in adults 20 to 30 per cent or more—a high proportion of the colloid infusion should be whole blood

Of the other colloids plasma or plasma expanders are used Following the lead of the Germans (Hecht and Weese Schulz) who developed the synthetic colloid polyvinylpyrrolidone (PVP) this and other plasma

* Cope and Moore in Boston, Evans and Butterfield in Richmond Truman and V Blocker in Galveston Artz and Reiss of Brooke Army Medical Center in Fort Sam Houston, Texas Pulaski in Washington D C., and the British Burn Units (Colebrooke, Squire Bull, and Jackson in Birmingham Wallace in Edinburgh and Clarkson and Evans in Basingstoke)

consists in exposing the burn wound to the air, thus permitting the exudate to dry (within two or three days), to form a hard crust that serves as a natural, occlusive, protective cover for the wound, in deep burns, the dead skin itself forms the occlusive eschar

There are protagonists for each method The purpose of each is to produce a dry wound, free from infection, and comfortable to the patient The exposure treatment seems to be preferred at the present time However, it appears to be far from the ideal treatment, and should not be used exclusively Its success depends much on the rate and effectiveness of drying of the burn wound by exposure to air Encircling burns of the limbs and trunk, which would require the utmost care to obtain a dry wound, are as a rule better treated by the closed method Burns of the hand should also be treated by the closed method, which permits immobilization in the position of function and minimizes edema formation, both important factors to counteract dysfunction It must also be pointed out that after-care of the burn wound requires much more attention in the exposure treatment than in the closed method On the other hand, in disasters the exposure treatment is the method of choice, since it requires little immediate care and no dressings

Technic of Pressure Dressing: The patient is placed on an operating-table, which is covered with a sterile sheet The operating-room personnel is prepared as for any other aseptic operation Oil and grease, if it had been used as a first-aid treatment, is removed with ether The area around the burn—not the burn itself—is gently washed with soap and water, if, however, the burn wound is dirty, it should be gently sponged with saline solution Blisters should not be opened, the unopened blister is a fine dressing and provides protection for the new epithelium growing beneath it, as Moyer so aptly points out The entire area is then flushed with copious amounts of warm isotonic saline solution and dried The injured surface is now smoothly covered with a few layers of fine-meshed sterile gauze, impregnated with petrolatum Over this are laid a half dozen layers of flat, dry gauze and a mass of gauze fluff, and over the fluff a layer of cotton or mechanic's waste to provide, under the retaining bandage, a resilient covering that produces an even pressure over the injured extremity or the burned surface without causing constriction An elastic bandage is then applied Burned limbs are immobilized with splints and elevated This dressing remains for ten days unless there is evidence of infection It is changed under sodium pentothal anesthesia, sloughs, which start to separate around the tenth day, are excised, and moist dressings with Dakin's solution are applied, followed

and food by mouth Occasionally gastric dilatation must be watched for this may simulate return of shock with signs of peripheral circulatory collapse and declining urinary output in spite of adequate fluid intake. A Levin tube should then be passed for gastric suction

It may be deemed advisable to strengthen the hormonal system The pros and cons of such therapy have been discussed on p 127

Admission Order The following is a routine admission order for the management of a severely burned patient before local treatment This is a modification of Blocker s admission order (1) Emergency sedation if required (2) Typing and cross-matching of blood draw blood for complete blood count and hematocrit repeat in twelve hours (3) Oxygen if required inspect for respiratory tract burns (4) Intra venous colloid isotonic salt, and glucose therapy according to formula (p 131) (5) No food by mouth for twenty four hours except by special order (6) Temperature pulse respiration and blood pressure every two hours for eight hours then every four hours (7) Skin test for tetanus antitoxin and administer 1500 units or if patient has had tet anus toxoid give 1 cc booster dose (8) Insert retention catheter and record hourly volume of urine (25 cc. per hour minimal satisfactory output) for twenty four hours then by eight hour periods immediate urinalysis repeat in twelve hours. (9) Record intake and output of fluids on proper form record emesis volume Record intake separately for forced feeding (10) Routine bacteriological culture (11) Peni cillin 300 000 units parenterally every twenty four hours (12) Photo graph patient. (13) Record history and physical examination for medi colegal records (14) Local treatment

Treatment of the Burn Wound

Only after shock treatment is initiated and the patient s general con dition stabilized should treatment of the burn wound be undertaken The popular methods of treatment are (1) by pressure dressing and (2) by exposure The advantages of the *pressure dressing* which ac cording to Blair was first advocated by White (1762) and later by Baynton (1797) are elimination of dead spaces control of oozing lim itation of venostasis and lymphostasis and reduction in the flow of plastic material into the wound. This method was popularized in the treatment of burns by Allen and Koch in 1912 The dressing consists in covering the wound with gauze which is impregnated with a bland ointment, followed by application of a heavily padded pressure dressing The *exposure treatment* which has been reintroduced by Wallace of Britain followed by Pulaski Artz et al and Blocker in this country

LATE TREATMENT

Further measures must be directed toward improving the patient's general condition, resurfacing the raw area in third-degree burns, and rehabilitation of the patient

Nutritional Measures· To maintain a good nutritional state and to prevent or counteract secondary anemia, frequent blood transfusions and administration of vitamins, particularly vitamin B complex, vitamin C, and iron in a high caloric diet, are necessary (see p 114) Blocker and associates regard the blood loss in severe burns as equivalent to a massive hemorrhage, hence, hemoglobin replacement must have priority over all other types of protein Other reparative processes require additional caloric and nitrogen intakes They emphasize that a severely burned patient should be supplied with protein and additional foodstuffs far in excessive of normal intake to combat the negative nitrogen balance after the first week of injury In this author's experience, Lund's recommended diet has been found to meet the nutritional requirements of the severely burned patient This mixture makes up a large part of the food necessary for twenty-four hours, and should be given in 8-ounce portions every two hours, day and night Meat and carbohydrate food may be given immediately after at least three liquid feedings Blocker prescribes

HIGH-PROTEIN MIXTURE FOR ORAL FEEDING

	Carbohydrate	*Protein*	*Fat*	*Calories*
Skim milk (3 liters)	150	110	6	1094
Skin-milk powder (300 Gm)	117	90	6	828
Amigen powder (100 Gm)	0	75	0	600
Valentine's liver extract (30 cc)	0	2	0	8
Salt (15 Gm)	0	0	0	0
Total	267	277	12	2530

HIGH-PROTEIN MIXTURE FOR TUBE-FEEDING

	Carbohydrate	*Protein*	*Fat*	*Calories*
Skim milk (3 liters)	150	110	6	1094
Skim-milk powder (200 Gm)	78	60	6	598
Amigen powder (200 Gm)	0	150	0	600
Valentine's liver extract (30 cc)	0	2	0	8
Brewer's yeast powder (30 Gm)	12	14	1	113
Salt (15 Gm)	0	0	0	0
Total	240	336	13	2413

later by saline-solution dressings Excision of all slough should be com plete by the third week so that skin grafts can be applied as early as possible. Enzymatic and chemical débridement of slough is still in the experimental stage

Technic of Exposure Treatment The initial cleansing is similar to that described in the foregoing paragraph The patient is then placed in bed on a sterile sheet, and the burned areas are exposed to the air burned extremities elevated The burned surface should not be in contact with the bedclothes or other parts of the body In body burns the sheets are kept away with the aid of a cradle In circumferential burns of the lower extremities in which ankles and feet are almost always spared elevation and exposure may be achieved by placing the feet over folded blankets a wooden board should be placed beneath the mattress under the buttocks In burns of the arms elevation may be made by means of a sling around the wrist the sling being fastened to an intravenous pole. The wound usually dries within two to four days to form crusts over partial thickness burns and eschars over full thickness burns The coagulum should now be inspected daily for cracks Loose parts around the cracks are trimmed Blocker covers these areas with a single layer gauze dressing moistened with saline solution In spreading infections crusts and eschars should be excised and moist dressings applied. The exposure treatment ends in partial thickness burns when complete heal ing has occurred, and in full thickness burns when eschar removal has been achieved The eschar starts to separate by the second week and should be excised under light anesthesia If it has not separated by the end of the third week all of it should be excised and the area prepared for skin-grafting by the application of moist dressings Granulating or raw surfaces should never be exposed. Skin grafts should be applied as early as possible

Antimicrobial Therapy It is essential that tetanus antitoxin or a booster dose of tetanus toxoid be injected upon admission of the patient. Antibiotic or chemotherapy is also started immediately (for details see p 115) Perineal gluteal and thigh burns may be partially protected from bacteria laden feces by giving sulfasuxidine (p 116) But in spite of potent antimicrobial agents chronic infection of the burn wound is un fortunately often the case and cross-infection of burn wounds when large numbers of burned patients are involved is frequent. The feasibility of Colebrook s layout of a burn center complicated as it may appear de serves much attention if wound infection and cross infection are to be reduced

antiseptic and analgesic ointments, such as butesin picrate, is recommended The latter is an excellent analgesic, but should be used with caution—that is, not repeatedly—since it may cause toxic symptoms *Second- and third-degree* burns require débridement and the application of an antiseptic analgesic ointment. The burned area should be protected with sterile dressings, application of splints may be necessary, ultimate treatment does not differ from that of extensive burns

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routinely from 3 to 4 Gm. of potassium chloride enteric-coated beginning about the fourth or fifth day if urinary output is adequate When the patient cannot or will not take this diet tube feeding may be indicated and such a mixture may have powdered yeast and more amigen added because palatability is no factor A suitable formula for this is shown on the preceding page

Skin-Grafting Another important factor that adds markedly to the improvement of the patient s general physical as well as mental condition is the early closure of raw surfaces with skin grafts This becomes necessary in third-degree burns but may also be required in deep second degree burns The earlier this is done the shorter will be the period of debilitation and the surer will contractures be avoided or counteracted The raw areas however must first be prepared for skin-grafting For details the reader is referred to p 28 For the use of split-thickness skin grafts including the indication for homografts, the respective passages should be consulted

Rehabilitation Last but not least it must be emphasized that a seriously burned patient, as a rule presents a psychological problem which naturally varies in degree. It is lessened if the patient has confidence in his surgeon from the start no matter how many other attendants he has the patient should feel that there is only one surgeon in charge of his case and that he can rely upon him then and in the future If this intimate contact is maintained—and it should be in spite of the fact that the surgeon s patience may be greatly taxed at times by the poor morale and complaints of the patient—psychotherapy may not become necessary This does not exclude the importance of daily visits from various staff members When dressings are changed pain should be avoided by sedation or by the use of light intravenous or inhalation anesthesia When skin-grafting is required the patient should be given a general outline of the plan and the expected results should be discussed Early ambulation if possible is important The services of the physiotherapist may then be sought Finally the occupational therapist must join as an important link in the long chain of efforts to solve the many faceted problems in equipping the patient for his new future

Treatment of Minor Burns

Minor burns may be regarded as burns of less than 5 to 10 per cent of the body surface In most instances they can be treated ambulantly unless the location of the burned area is such as to require hospitalization Usually they require no general treatment except for the relief of pain by administration of a sedative In *first-degree* burns application of

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V

OPERATIVE CORRECTION OF SCARS

SCARS usually follow the destruction of tissue resulting from trauma, burns, operation, or disease. Their appearance, their painfulness, or their contraction may cause mental or physical handicaps Before operative correction is undertaken, the tissue which formed the scar must have reached a state of quiescence, recognizable by the pale color and softness of the cicatrix Massage and radiation often aid in accelerating the process

In discussing the plastic repair of scars, it is important to distinguish between simple and extensive scars Both types can be smooth, hypertrophic, depressed, or contracted

Simple Scars

Simple Smooth or Hypertrophic Scars: The simple scar, whether smooth or hypertrophic, is not always easy to correct It is outlined by an incision, which penetrates at either side of the scar to the subcutaneous tissue, but not deeper The subcutaneous tissue is kept intact to act as a basis upon which the wound edges should be approximated (Fig 51) With a sharp knife, the scar is excised The wound edges are mobilized and separated from the subcutaneous tissue in a circumference of about 1 cm (3/8 inch) Exact hemostasis is the next step If possible, ligatures should be avoided and the bleeding controlled by pressure with hot, moist compresses If ligatures are unavoidable, they should be made with the finest silk or cotton The sutures of the wound edges are interrupted, and should be with fine nylon or silk, on a fine, curved cutting-edge atraumatic needle The wound edges are

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not grasped with forceps but merely elevated by one prong to facilitate the penetration of the needle If the wound edges are thick, interrupted subcutaneous sutures with fine cotton should precede the skin sutures The sutures are led so that the knot comes to lie toward the base of

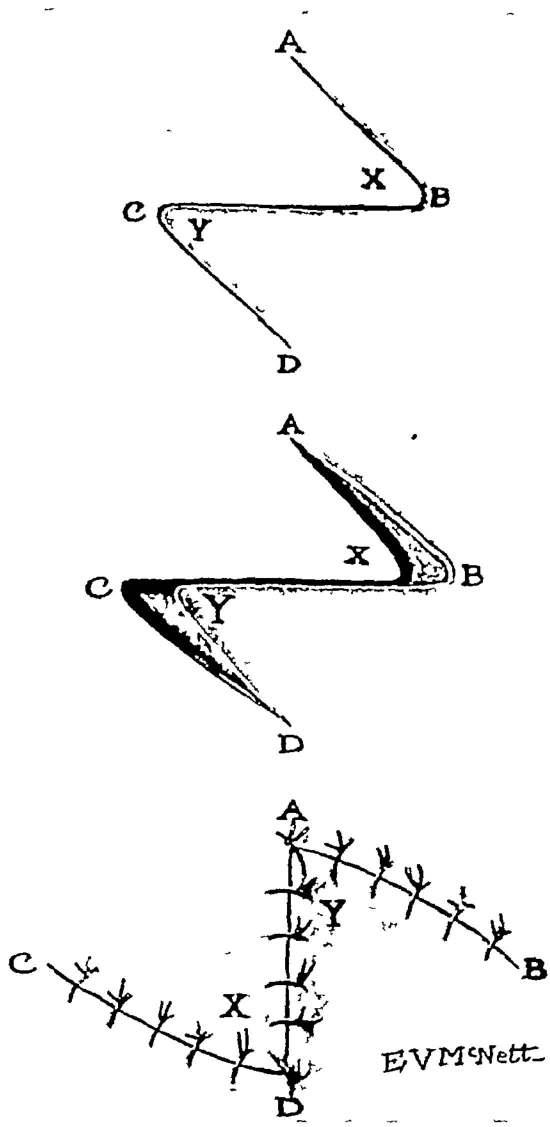

Fig 53 Z-operation for contracted scars due to binding webs Central line of Z is laid upon most prominent portion of web, arms of Z marked out on opposite sides of central line in 45-degree angles Points *A* and *D* should lie in vertical projection of center of *C* and *B* Thus, two triangular flaps are outlined, which are mobilized and exchanged. Object is to interrupt and displace binding web (note different direction of central line and increased distance between *C* and *D*) (After J S Davis Pennsylvania M J)

the scar (Fig 52) If the wound edges are not under tension and are straight, Halsted's subcuticular wire suture is of value (Fig 4) (Case 17, p 870) The wound is covered with silver foil, which keeps it dry and aseptic, or with xeroform ointment (see p 34) The sutures are removed between the third and fifth day after the operation

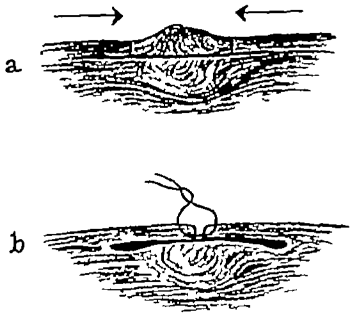

Fig. 51: Correction of simple smooth or hypertrophic scar. Incision outlines scar and penetrates on each side of scar into subcutaneous tissue, but not deeper Subcutaneous tissue is kept intact to act as basis on which mobilized wound edges are approximated.

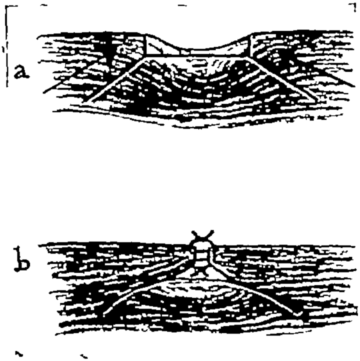

Fig. 52: Correction of simple depressed scar Scar is excised to base of retracted area. From deep corners of defect, bilateral incision is carried obliquely downward and outward, leaving base of scar intact to act as buttress. Mobilized wound edges are approximated upon this buttress.

Extensive Scars

Extensive Smooth Scars: Extensive smooth scars are in the same plane as the skin Ordinarily, they do not cause any trouble, since they do not contract. They tend to become annoying, however, if they are situated in such exposed regions as the face or neck. In these cases, repair work may be requested If the scar is not too extensive, is elliptical, and the surrounding skin is freely movable, the scar is treated as if it were simple and smooth It is excised down to the subcutaneous tissue, but not farther. The wound edges are mobilized subcutaneously and approximated until a linear suture can be established If the defect left after excision of the scar is triangular (Fig 12) or rectangular (Fig 13) and the surrounding skin is freely movable, plastic closure can be achieved by starting with closure of the corners. If undue tension in the sutures is to be anticipated, a multiple-stage procedure is advisable, by which the scar is only partly excised and sutured (Morestin, Sistrunck, Smith) During the intervals — the intervals being three months — the skin is allowed to stretch until all parts of the scar are removed.

If the scar is too large to permit closure of the defect by simple tissue mobilization or tissue-sliding, covering the defect by a full-thickness skin graft or thick split graft is advisable (Case 19, p 872)

Extensive Hypertrophic Scars: The hypertrophic scar passes through a series of phases During the healing stage, it becomes raised and looks red Gradually, however, it fades out and recedes in prominence until it is on a level with the skin Should, however, the scar maintain its prominence or become thickened and, as so often occurs, be accompanied by itching, it then has developed into a keloid Until recently, we did not know the cause of the keloid (the literature up to 1942 had been well reviewed by Garb and Stone) More light, however, has been thrown upon the subject by Mowlem, and by Gluckmann in collaboration with Fell and Levitt, who investigated the cause of scar hypertrophy It seems that if hair follicles, sebaceous glands, and their remnants become buried within the scar, the keratin liberated from these structures causes an extreme tissue reaction The latter can be avoided or at least lessened if the scar is irradiated for the purpose of damaging the buried hair follicles and glands However, true keloid scars are still a problem It is a well-known fact that even after a complete excision of a keloid, it may recur after a few weeks, whether the defect is sutured primarily, covered by a skin graft, left to granulate, or is electrocoagulated Local injections of the enzyme hyaluronidase, either alone (Cornbleet) or with corticotropin (ACTH) (Conway and Stark), appear to have questionable effect upon reduction of the keloid, although they seem to relieve itching

Simple Depressed Scars If the simple scar is depressed the technic for correction differs. The incision outlines the scar and penetrates at either side to the base of the retracted area but not farther The scar is now excised as previously described From the deep corners of the defect, a bilateral incision is carried obliquely downward and outward, leaving the base of the scar intact to act as a buttress (Fig 52) The adjoining tissue thus mobilized is approximated upon this buttress and transfixed with interrupted subcutaneous fine cotton sutures and skin sutures or a subcuticular running wire suture (Case 17 p 870) The stitch of the subcutaneous suture is led so that the knot comes to lie toward the base of the scar

Simple Contracted Scars If the simple scar is contracted the entire scar tissue including the base must be excised until the whole defect thus created consists of normal tissue. One ordinarily succeeds now in releasing the contracture unless it has been of long standing Usually some sort of tissue-shifting rarely skin-grafting is necessary to close the defect

In cases where the contracture is due to a binding web the Z type of relaxation incision with exchanging flaps is the operation of choice. The object of this operation is to interrupt and displace the binding web by the formation and transposition of two triangular flaps which are placed so that their outlines form a Z. The central line of the Z is laid along the most prominent portion of the web and the arms of the Z are marked out on opposite sides of the central line The two triangular flaps thus outlined are mobilized The contracture is now reduced as far as possible and the two flaps are transposed (Fig 53) If the binding web is long several such Z s may be formed and their flaps transposed as demonstrated in Case 95 p 975

The Z plastic procedure can be applied in many other ways (Dingman) A good example is the breakup of congenital webs of the neck with the multiple Z-operation (see p 457) The multiple Z plasty is also of great value in overcoming amniotic furrows of the extremities as suggested by Stevenson (Farmer Blackfield and Hauser) and in correction of constricting bands which involve the fingers more frequently than the extremities They are of various degree ranging from superficial furrows to deep grooves and actual amputations The central line of the Z comes to lie upon the constricting band while the arms are made on the opposite sides As a rule several such Z s are necessary In some cases particularly those with lymphedema a several-stage operation (with intervals from one to several months apart) is advisable (Case 138 p 1038)

and pain The most efficient treatment remains radiation by x ray or radium preferably after excision of the scar If the keloid extends over an area where the skin is freely movable one may attempt excision of the entire area The skin surrounding the defect is mobilized and approximated until a linear suture can be established. Radiation is applied postoperatively as soon as the wound has healed If the scar in spite of excision and radiation develops again into a keloid the second is many times smaller than the first (Fig 13)

Extensive Depressed Scars If an extensive scar is retracted or depressed the technic of correction differs from that used in simple depressed scars In the majority of cases, the involved area is too large to allow an approximation of the neighboring subcutaneous tissue to fill the defect Hence the repair work involves grafting with fat derma bone or cartilage to restore the normal surface contours. The scar is excised down to its base The skin surrounding the defect is mobilized then after careful hemostasis a properly shaped graft of fat fascia cutis bone or cartilage is transplanted into the defect before the skin is closed over it (see Chapter II) (Case 12 p 861) If simple mobilization of the skin does not suffice to close the defect over the graft additional incisions must be made to allow more liberal shifting or rotation of skin In such cases however secondary defects may be left, and one must be sure that they can be closed (see Chapter II) In extreme cases transplantation of skin by pedicle flaps is the last resort.

Extensive Contracted Scars. Correction of extensive contracted scars is one of the most difficult problems in plastic surgery The extensive contracted scar is usually caused by destruction of the deeper parts of the surface tissue and appears usually at the flexor surface of the extremities or at the junction of limb and trunk. In some cases much can be done to avoid them to a greater or less degree by proper immobilization of the affected limb during the healing stage Before any operative correction is undertaken one should wait until the scar tissue has reached its final stage although waiting too long may cause ankylosis and shortening of tendons and ligaments Active and passive motion exercises of the affected limb and radiation during the waiting time are advisable The objects of treatment are to remove the scar to replace it by normal tissue and to restore function For technic the reader is referred to pp 560 689 and Cases 2 p 846 97–101 pp 978–984

Surgical Abrasion In 1947 P C. Iverson of Philadelphia introduced surgical abrasion which he had devised for treatment of land mine tattoos during World War II This ingenious novelty was immediately received with great enthusiasm its field of application was soon widened and

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this treatment is highly recommended With a fine-grit abrasive a super ficial denudation of the scar and adjacent epithelium is produced before the scar is excised the wound edges are sutured in the usual way and covered with a strip of rayon (p 36) The sutures are removed on the fourth postoperative day by cutting the covering strip of rayon over the suture line only The remainder of the dressing remains in place until it peels off on its own accord.

Technic for Extensive Abrasion (Case 18, p 871) The procedure is carried out under general anesthesia or local infiltration anesthesia (1 per cent procaine with epinephrine—5 to 10 drops per ounce for hemostatic purposes) or by the use of the ethyl chloride spray (Kurtin Burk) Ordinary waterproof emery paper of various grit (available in any hard ware store) cut in strips equal to the width and circumference of a 3-inch bandage and wrapped around the bandage is used for the abrasive Smaller pieces may be cut to wrap around a Freer perichondral elevator or curved hemostat to reach crevices or treat narrow areas more effec tively Recently motor-driven (1200 revolutions per minute) sanding cylinders (Iverson) or wire brushes of various widths (Kurtin Burk) have been recommended. After the surface is surgically prepared it is abraded vigorously Capillary oozing can be decreased by applying com presses soaked in epinephrine solution It is safe to carry abrasion if nec essary to the point where subcutaneous tissue gradually makes its first appearance in pin point elevations of fat through the abraded corium Isolated areas more deeply embedded and requiring removal should be ex cised rather than abraded the wound edges are sutured At the end of the procedure the raw surface is rinsed with copious amounts of warm saline solution to prevent emery particles from becoming buried under the regenerating epithelium The raw surface is then covered with strips of rayon soaked in epinephrine solution No other dressings are required The rayon strips become adherent in a few minutes They are left in place until they peel off usually after from eight to twelve days.

The erythema of the new skin gradually fades in from eight to ten weeks. If a second-stage abrasion of the same area is required it should not be carried out before this time Within this time a small percentage of patients may develop small white pinpoint milia which are probably due to new epithelium over some of the sebaceous glands They rupture spontaneously or can be evacuated after puncturing with a sterile needle

DIVISION TWO

THE HEAD AND NECK

seek seclusion, and develop a hatred of normal-looking people Correction of the deformity may overcome this complex, and may also restore harmony to the facial features, in some patients, however—particularly those with profound personality handicaps—even the finest surgical results will not overcome the inferiority complex These patients require, aside from surgical treatment, the therapeutic services of a psychiatrist.

The various reconstructive procedures for correction of facial deformities or defects can be divided into certain groups. (1) cheeks, temples, head, (2) lips, (3) nose, (4) lids, and (5) ears. But it is only natural—particularly if dealing with large defects—that some of the reparative problems cannot be forced into ordinary classifications Hence, if a surgeon is accustomed to working according to prescribed methods, he is apt to become disappointed. Imagination and artistry must go hand in hand with skill and knowledge to lead to the final result, the success of which can be judged only by a consideration of the gravity of the case, that is, in the light of comparison

Anesthesia in Surgery of Head and Neck

Agents: The most frequently used anesthetic agents in surgery of the head and neck are *ether,* either alone or in combination with the gases, the *gases,* such as nitrous oxide, ethylene, and cyclopropane, *pentothal sodium,* either alone or in combination with the gases or solution of tribromoethanol (avertin), and *procaine,* either alone or in combination with pentothal sodium or solution of tribromoethanol

Methods of Induction: For operations around or in the *mouth,* one may use local anesthesia, nasal or oral endotracheal inhalation, or intravenous pentothal sodium (alone or with nasal or oral endotracheal intubation) The purpose of nasal endotracheal tubes is to assure the patient of an adequate airway and to permit a clear surgical field If inhalation anesthesia is to be used and no facilities are available for endotracheal intubation, anesthesia is induced by the conventional mask or open-drop method After the proper plane of anesthesia has been obtained, sterile bilateral nasopharyngeal tubes, which are connected with the ether delivery tube, are inserted For children under fourteen years of age, pentothal sodium should not be used Open-drop ether anesthesia is the method of choice Having obtained the desired plane of anesthesia, one continues the anesthesia by means of an anesthesia hook, which is placed in the angle of the mouth and connected to the ether delivery tube.

In operations about the *nose,* the preferred forms are local anesthesia, oral endotracheal inhalation, and intravenous pentothal sodium If no

VI

INTRODUCTORY ASPECTS OF HEAD AND NECK

THE individual appearance or expression of the face and head of a person results mainly from the conformation of the framework of the head and its surrounding soft parts. In numerous places where the framework is covered only by skin and subcutaneous tissue the framework alone dominates the characteristic features, such as at the ridge of the nose, at the rim of the orbit, and at the zygomatic arch. In other places, where skin and framework are separated by muscles, the muscles not only are additional factors in causing the characteristic features but also provide mimic and other functions, such as the opening and closing of mouth and eyes.

General Considerations

The aim of any reconstructive operation must be the restoration of form and function. While in some parts of the body restoration of function is the major issue, in exposed parts—particularly in the face—restoration of form is of equal importance. Any external part of the body appears misformed if it differs in shape and proportion from normal appearance. The transition from normal to abnormal forms may be either slight or very noticeable. Particularly in the face, any slight deviation from the normal characteristics of a race may become noticeable, making the patient feel self-conscious and causing considerable mental distress. The feeling of having an abnormal appearance is usually reflected in the face, causing a change of the physiognomy, which is under psychic influence. For a certain type of patient, disfigurement of the face is more tragic than fear of death. These patients become depressed; they

VII

THE CHEEK, TEMPLE, AND SKULL REGIONS

REPARATIVE surgery of the cheeks and the temple and head regions is divided into (1) the closure of defects and (2) the correction of deformities

Defects

A defect in these regions may be simple or complicated It may involve the surface structures only or deeper structures including the framework. A defect may be caused by the surgeon himself or may already be present In the former case, the surgeon is, to some extent, at liberty to give the defect the shape he wants and may thus often facilitate its closure (see discussion of Langer's lines, p 13, and Fig 11) In defects already present he is confronted with a predetermined problem

DEFECTS INVOLVING SKIN ONLY

There are certain defects which involve the skin alone, without the subcutaneous tissue. These defects may be due to trauma, excision of scars, or excision of skin tumors There are two ways of closing these defects by skin-sliding or skin-grafting

Skin-Shifting: Skin-shifting should be employed, as a rule, only in small defects, since it involves wide subcutaneous undermining of the skin (separation of the skin from its nourishing base), and hence offers the possibility of necrosis or of secondary deformity In some cases, this can be avoided by utilizing a several-stage procedure, such as described on p 148. The mole or scar, for instance, is partly removed and the defect closed by skin-sliding After the skin has stretched—that is, after three months—one or more similar procedures are performed

facilities for endotracheal intubation are available and ether anesthesia is desired, the patient is anesthetized by the open-drop method and—after the proper plane of anesthesia has been reached—anesthesia is continued by means of an oral pharyngeal airway which has a built in tube that can be easily connected to the tube delivering the vaporized ether

For operations about the *orbital region*, anesthesia is induced by methods similar to those used in operations about the nose, with the exception that nasal endotracheal inhalation may also be employed.

Any of the foregoing methods may be used for operations on *ears*, *forehead*, *scalp*, and *neck*

For details on these various methods of anesthesia the reader is referred to standard texts on anesthesiology

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Flaps or Split Grafts for Scalp and Periosteum: Defects of the scalp which do not include the periosteum are best covered with thick split grafts The periosteum is an excellent base for the growth of free grafts The most extensive avulsions of the scalp are incurred by female factory workers whose hair is caught in conveyor belts, rolls, and other machinery (Case 10, p 858) If the general condition of the patient is satisfactory, the raw areas should be covered immediately by split-thickness grafts Attempts to replace the avulsed scalp in its original form have invariably failed (Robinson) Osborne, however, reports success in the application of split grafts from the shaved and aseptically prepared avulsed scalp with the dermatome, using Zintel's split-split technic. Defects which include the periosteum, exposing the naked bone, are best covered with flaps taken from the preserved parts of the scalp. Before one resorts to this method, however (this is particularly true in extensive avulsions of the scalp), a more conservative method may be given a trial removal of the outer table of the skull with a chisel to expose the medullary spaces and to promote the growth of granulations, followed by transplantation of a split graft This procedure has been successful in one of the author's cases, and is also highly recommended by Kazanjian and Webster. It may not even be necessary to wait until granulations have formed but instead to transplant the grafts immediately upon the medullary space (Case 9, p. 856), as is done after saucerization of other bones If this does not succeed, the flap method should be used The flap should be planned to contain one of the larger arteries (temporal, frontal), because of the abundant blood supply of scalp flaps they can be transferred immediately Care should be taken that the periosteum of the donor area is not included in the flap but left behind upon the bone The periosteum is an excellent base for a skin graft Hence, after transfer of the flap, the raw area of the flap bed can be covered with a split graft immediately, which invariably takes well (Cases 1, 3, 8, pp 844, 848, 854) If a sliding flap cannot be used—the defect may be too large—a tube flap from the abdomen migrated via the forearm should then be selected (Bagozzi)

DEFECTS OF SKIN AND MUSCLE

Defects of this type are best covered with pedicle flaps to which a sufficient amount of fat tissue is attached. For defects of *muscles,* see under Deformities, p 180)

DEFECTS OF FULL THICKNESS OF CHEEKS

Defects involving the entire thickness of the cheeks require replacement of skin plus lining. There are numerous ways possible, and many

Skin-Grafting For larger defects skin-grafting is the method of choice (Cases 2 4 19 pp 844 849 872) The indication for the various types of grafts has been outlined on p 24

In skin defects due to burns with roentgen rays one word of caution may be said concerning skin-grafting a free graft will take only on healthy well vascularized tissue. In some x ray burns the burn may involve deeper structures causing dense avascular scar formation of the subcutaneous tissue Such tissue is a contraindication to free grafting transplantation of a flap should preferably be considered.

DEFECTS OF SKIN AND SUBCUTANEOUS TISSUE

Tissue-Shifting and Flaps from Immediate Neighborhood If a defect involves skin and subcutaneous tissue free skin-grafting as a rule is out of consideration since skin and subcutaneous tissue need to be replaced Such a defect is covered either by tissue-shifting or by means of a pedicle flap Tissue shifting (Figs 14–16 Case 5 p 850) has the great advantages of tissue resemblance and quick healing The same is true with flaps taken from the immediate neighborhood The secondary defect resulting from transfer of the flap may be placed in hidden areas (Cases 1 3 7 pp 844 848 852)

Flaps from Distant Parts. Next in choice is a flap from a distant part of the body Available is the forehead flap or one of the tube flaps The forehead flap (also the sickle flap p 300) best matching cheek color and texture should in males be used only if necessary for it leaves scars and a denuded area which in spite of skin-grafting may be dis figuring In females however it is the flap of choice if the patient is willing to alter her hair style In males, a hairbearing flap from the scalp containing the temporal artery may be occasionally useful if haired skin is to be replaced (Case 30 p 888) Of the tubed flaps the vertical or horizontal (mastoid to mastoid) cervical flap is perhaps the simplest since it can be transplanted directly secondly if the flap is planned so that the skin of the clavicular region becomes the peripheral end of the flap it will well match the skin of the cheeks (Case 6 p 851) Next in choice is a flap from the upper arm (Case 13 p 862) Flaps from other regions provide more skin but do not so well match the skin of the cheeks and also need successive migration by the use of intermediate host areas (Case 11 p 860) Where the flap comes to lie on the naked bone of the skull the external table of this bone should be removed and the medullary spaces exposed to facilitate adherence of the flap's raw surface to the base of the defect.

useful (Blair). The pedicle flap should have a hairless skin (cervical or acromiopectoral) flap The flap is introduced through an incision below the mandible The incision, commencing at the anterior border of the masseter muscle anterior to the crossing of the arteria maxillaris externa, is led forward and penetrates between cheek and mandible The flap is sutured in place after removal of all scars and reduction of the contracture The pedicle is severed after from two to three weeks, followed by adjustment of the flap and proper closure of the wound along and below the mandible

DEFECTS OF SKULL

Defects of the skull may cause deformity as well as functional impairment and symptoms (traumatic epilepsy) Closure of such a defect can be achieved with autogenous or heterogenous material The preferred autogenous material is the bone graft (Lexer, Gulecke, Grant and Norcross, McClintock, Dingman, and others) Of the heterogenous material, vitallium (Geib, Peyton and Hall, Beek), celluloid (Ney), and tantalum (Pudenz, Mayfield and Levitch, Gardner, Woodhall and Spurling, Weiford and Gardner, and others) have been used Tantalum has gained popularity The recent concepts of this subject have been well covered by Reeves in a monograph that also contains an up-to-date collection of references He prefers tantalum plates More recently, Dingman strongly advocates autogenous bone plates Autogenous material becomes an organic unit with the host bone, heterogenous material becomes encapsulated Tantalum, however, appears to induce less tissue reaction than the other foreign materials, but it remains a foreign body, and as such may upon injury cause infection, which is the chief source of failure in cranioplasty This is unlikely when autogenous bone grafts are used, particularly after the bone graft has become incorporated as an organic unit, this outweighs the apparent disadvantage of the greater magnitude of the operation

Closure of Skull Defect with Autogenous-Bone Graft *Technic* The covering skin receives first attention Any broad scar must be replaced, preferably by skin-shifting or transfer of a pedicle flap (see p 16 and Case 8, p 854) a few weeks before the main repair work After traumatic injury, it is still believed wise to postpone the closure of the skull defect for three months after primary healing and six months after infection In preparing the bone-graft bed, it is to be emphasized that (1) cranial periosteum is to be preserved, otherwise, a periosteum-covered graft must be chosen, (2) the preparation of the defect's edges is to be done in such a way that a broad apposition of graft and host bone is possible The defect is exposed by forming and reflecting a properly

methods have been described but only a few of them are worth while from the cosmetic standpoint. All those methods which employ local flaps in such a way that they leave disfiguring scars should be discarded.

Local Flaps. These should be used only for closure of small defects. The principle consists in the formation of a flap from the direct neighborhood of the defect its pedicle is sutured to the bordering mucosa to obtain maximal blood supply at its base. Later on the flap is turned over to replace the lining and another flap from the neighborhood is rotated or slid to cover the raw areas. The defect left by the latter is closed by skin sliding (F Smith)

Technic (F Smith) (see Fig 69 for Comparison) The flap to be utilized as the lining hinged flap is outlined It must receive its blood supply from the lining mucosa and the muscles bordering the defect Consequently the mucosa on this edge must be undermined and accurately approximated to the skin of the pedicle with fine sutures This produces a minimum scar and a maximal blood supply The blood supply may be guaranteed by partial mobilization of the flap and returning it to its original site The next step (three weeks later) consists if necessary in destroying the hair follicles of the lining flap by shaving off (with a skin graft knife) a layer of epidermis sufficiently thick to destroy them The raw area is covered with a split skin graft. Two weeks later the lining flap with some of the underlying fat tissue is turned over and sutured to the incised free margins of the mucosa of the defect. The raw surfaces are covered with a flap rotated or slid from the neighborhood the defect left by the latter is closed by skin-sliding The blood supply of the covering flap may be guaranteed by mobilization and returning it to its former site during one of the previous stages The muscle defect if it results in a depression may be corrected later on by transplantation of a dermal graft

Flaps from Distant Parts For larger defects flaps from distant parts must be chosen (Case 14 p 864) These flaps must of course be lined Concerning the source and lining see p 68 (compare also with p 213 Transplantation of Distant Flaps)

DEFECTS OF LINING OF CHEEKS

Large defects of the lining mucous membrane due to trauma or infectious processes cause early contractures These contractures should be released as soon as possible and the defect covered either with a split skin graft according to the inlay or onlay method (p 37), or with a pedicle flap Grafts should be used in cases where only the mucosal lining is to be replaced for deeper defects a pedicle flap is indicated and most

GRAFT FOR LARGE DEFECT· For larger defects, the graft should be taken from the ilium or from the anterior surface of the tibia and be about 0 5 cm. (3/16 inch) thick (Fig 55). The graft from the ilium is given preference. If a periosteum-covered tibial graft is used, it is bent by sawing transversely through the cortex to, but not through, the periosteum. If more than one plate of graft is needed, the defect is covered as outlined in Fig 55, *b* It is important not to place the plates side by side,

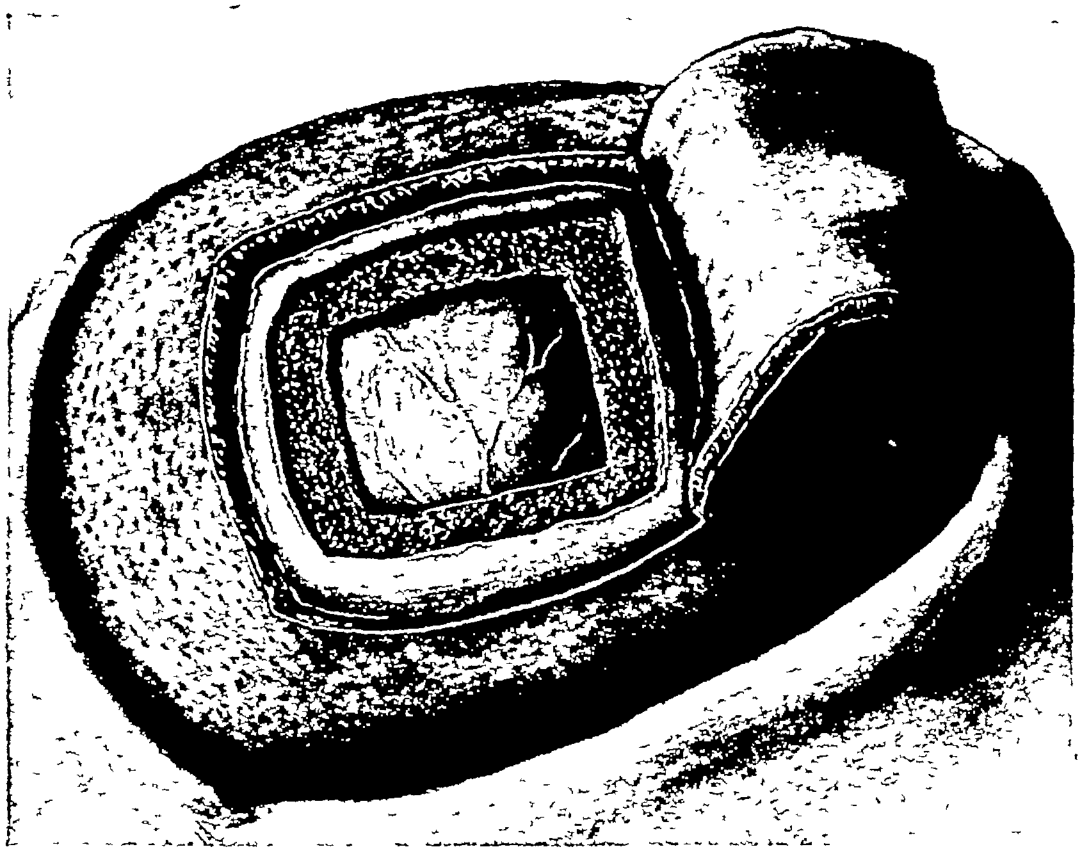

Fig 55, *a* Closure of large skull defect with autogenous bone graft Scalp flap for exposure of defect is reflected Graft bed is prepared by removal of external table around defect edges

but to overlap them, this requires shaping of the edges in a staircaselike manner In this way, the grafts are in broad apposition not only with the defect's edges, but also with each other They are held in place with long mattress sutures of cotton If ilium grafts are used (see Case 8, p 854), they are removed from the inner table of the ilium, as recommended by Pickrell and described on page 64 Coming from the median side of the pelvis, they are naturally curved The concave side, which comes to lie upon the dura and brain, is smooth and covered with periosteum As large grafts must be used, it may be necessary to remove the median rim of the crest of the ilium, together with the median plate The graft is

shaped scalp flap The flap should be made larger than the underlying bone defect so that its wound edges do not superimpose upon the edges of the cranial defect. The dura is carefully dissected free. Then the medullary spaces of the bony defect s edges are exposed for at least 1.5 cm. (⅝ inch) by removing the external table thus preparing a broad well vascularized graft bed (Figs 54 55 *a*) This is done as follows At a distance of about 1.5 cm (⅝ inch) from the defect s edges a shallow groove is carved in the bone with a V-shaped chisel Then with a flat chisel the external table is removed from the bone edge to the groove.

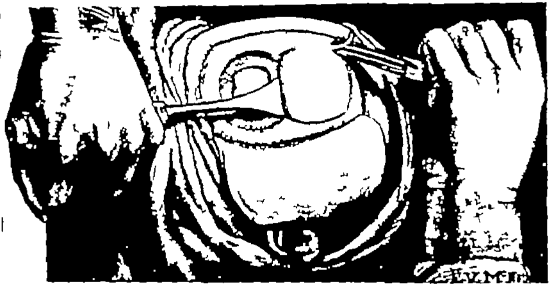

Fig. 54: Closure of medium-sized skull defect with tabula externa graft. Scalp flap reflected. Graft bed prepared by removal of rim of external table around defect edges. Tabula externa graft being removed.

GRAFT FOR SMALL DEFECT Now follows the removal of the graft Only seldom will the classic method of Müller and König be possible they shifted a pedicle flap (skin periosteum lamina externa) from the neighborhood into the defect. But a free lamina-externa graft for defects not larger than 5 by 5 cm (2 by 2 inches) is the graft of choice (Fig 54) It is best taken from thick parts of the skull such as the occipital region An extension of the incision or a secondary incision for exposure of the occipital region may become necessary The periosteum should be left attached to the graft if a periosteum-covered graft is needed A pattern of the defect is made and placed upon the donor area With a V-shaped chisel a groove is made around the pattern down to the diploe and with a straight chisel held almost flat the graft is removed The graft is now laid upon the defect and its periosteum sutured to the periosteum of the defect s edges.

a fat-tissue graft (Drevermann) The operation is then carried out in two stages (1) removal of scar from the brain and transplantation of the fat-tissue graft, and (2) closure of the bone defect with bone grafts three months later

Closure of Skull Defect with Tantalum Plate. *Technic* The defect is exposed and the defect's edges prepared as just described The groove in the outer table encircling the defect, however, is made less wide and less deep A sheet of tantalum, 0 3 mm (0.0125 inch) thick, is shaped at the operating-table to fit into the prepared groove and to conform with the contours of the skull The necessary implements are a pair of tin-shears, a metal punch, a round-headed hammer, and a concave wooden block (Gardner) The plate is then set upon the prepared bone shelf and held in place with small tantalum screws, drilled through punch holes of the plate into the bone The skin flap is reflected back and the wound edges sutured

After-Treatment. A well-padded dressing is worn until the wound has healed Postoperative fluid collections between scalp and implant may be aspirated or controlled by a pressure dressing.

DEFECTS OF STENSEN'S DUCT (SALIVARY FISTULA)

Injuries to the ductus parotideus may occur in the region of the parotid gland or of the masseter or buccinator muscle Injury to the buccal and zygomatic branches of the nervus facialis is also likely to be present If the division of the duct is overlooked or primary repair neglected or unsuccessful, distressing fistulas of the duct may develop, and may offer difficulties in successful repair Hence, it is most desirable to attempt a primary repair, which in clean-cut wounds can be performed up to twelve hours after the accident Repair of the fine-caliber facial-nerve strands should not be attempted, since it is hardly possible and spontaneous regeneration nearly always occurs The literature on primary repair of the severed parotid duct has been thoroughly reviewed by Sparkman From his experience, it becomes evident that a dowel should be inserted into the severed ends only temporarily while the divided ends are being anastomosed, and also that postoperative salivary secretion should be augmented to counteract obstruction rather than suppressed Hence, as soon as it is feasible, the patient is placed on a regular diet Oral hygiene with frequent mouthwashes should be maintained pre- and postoperatively

Technic. *Primary Repair* After the usual cleansing and under local anesthesia with 1 per cent procaine, bleeding is controlled and the severed duct ends are exposed Lacerated oral mucous membrane and

properly shaped with rongeur and chisels To obtain additional curvature of the graft the margins may be bent with pliers and broken in greenstick fashion The graft is then placed upon the cranial defect s edges and held in place with long mattress sutures of cotton similar to those demonstrated in Fig 55*b* The skin flap is now replaced and sutured If there was much oozing, it is wise to insert two fine rubber dam drains at the most dependent points for forty-eight hours

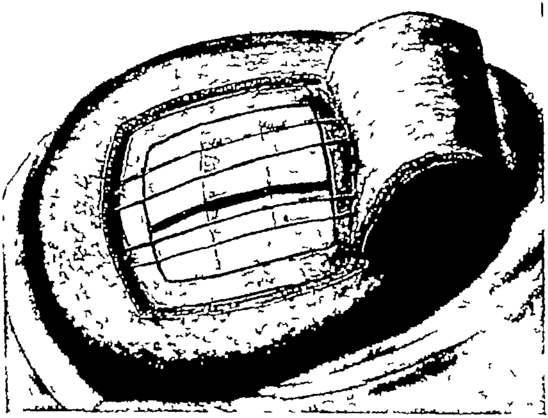

Fig. 55 *b:* Two periosteum-covered tibial grafts are placed upon graft bed and held in place with mattress sutures. Grafts have been bent after sawing transversely through cortex in two places to periosteum, but not through it.

After Treatment A heavily padded pressure dressing is applied and antibiotics are administered The dressing is changed after forty-eight hours and a moderately padded dressing applied until removal of the sutures on the eighth postoperative day The grafted cranial area must be protected by means of well padded dressings for about three weeks

Traumatic Epilepsy Traumatic epilepsy is benefited by cranioplasty alone as the follow up studies of Grant and others demonstrate (see Case 8 p 814) There are however opinions to the contrary Lexer recommended for cases of dural defects replacement of the cicatricial tissue with

each square to hold the thread snugly in place. The incision is now closed

After-Treatment This consists in routine administration of antibiotics, mouthwash, and liquid diet until the initial swelling has subsided, a watery fluid will drain from the wound for about a week The suture dowel may be removed after the fourteenth postoperative day, provided all the swelling has subsided

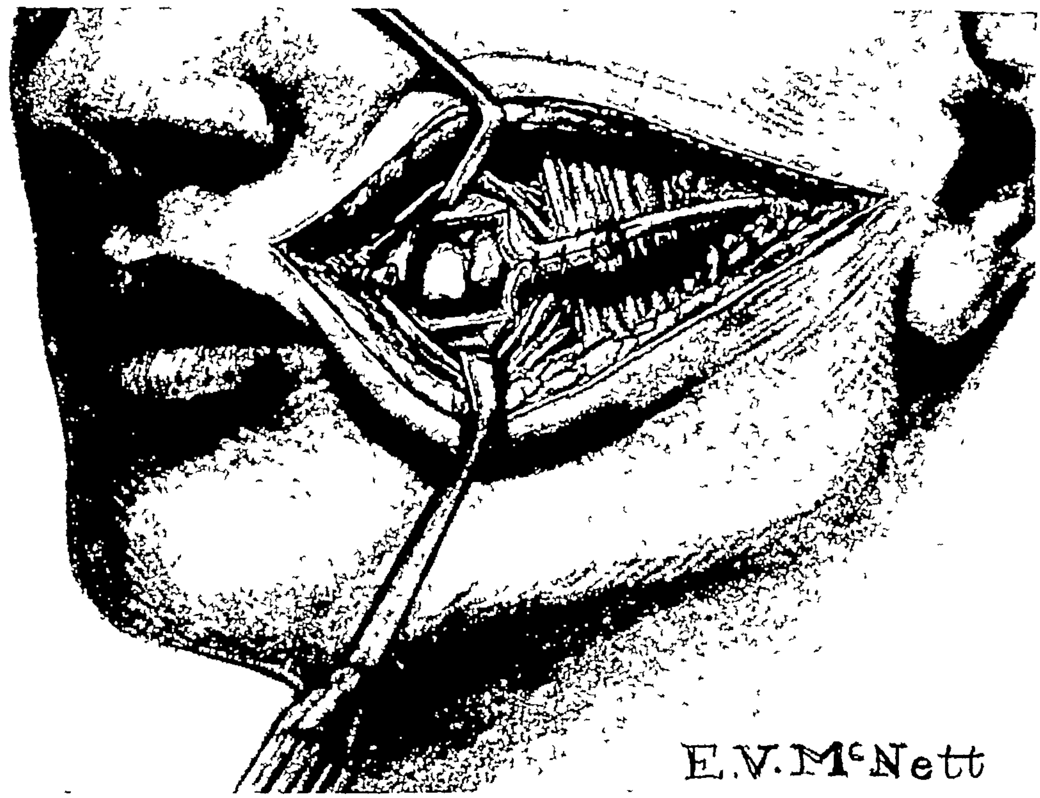

Fig 56 Repair of defect of Stensen's duct with tubed buccal mucous-membrane flap (Kuttner) Mucous membrane has been exposed through opening in buccinator muscle

If the papilla of the duct in the mouth is destroyed or obliterated and the central end of the duct is sufficiently long, it can be rerouted into the mouth

Technic (Langenbeck) If an external fistula is present, a probe is inserted, and the fistula is circumscribed by an incision, which leaves a small disk of skin attached to the external opening (Delore) From here, the central part of the duct is dissected free for a short distance A perforation is now made in front of the masseter muscle through the buccinator muscles and the mucous membrane of the mouth The freed part of the duct is pulled through this opening into the mouth and held in this position by suturing the small disk of skin to the edges of the mucous

muscles are sutured first A small-caliber urethral catheter is inserted into the distal portion of the duct while the other end of the catheter is cut on a bevel and placed into the proximal portion The anastomosis of the divided duct ends is now accomplished over the catheter with interrupted everting mattress sutures of finest silk on an atraumatic needle (compare with Fig 29) The catheter is then withdrawn through the mouth and the wound is closed.

If the laceration of the duct is overlooked or primary repair is unsuccessful a salivary fistula will usually develop and may be external or internal Fistulas of smaller branches of the duct in the gland region heal spontaneously fistulas of the duct proper often do not and require repair If the gap between the peripheral and central ends of the duct is not excessive simple suturing of the two ends after their mobilization over a dowel may be tried as described previously the dowel is removed after completion of the anastomosis In the majority of cases however the duct ends cannot be united or the anastomosis would be under tension In such cases short-circuiting operations with rerouting of the central end into the mouth have been advised, but should be reserved only for extreme cases (see below) since this method does away with the valve like action of the papilla and there is no protection against ascending infection from the mouth Instead it is recommended that the two ends be bridged with a dowel which should remain in place for from two to three weeks The use of a dowel with a lumen (urethral catheter) is not necessary since most of the saliva passes between dowel and mucous membrane While the flow of saliva is augmented after anastomosis it should be slowed when a gap is present. Bailey and Saff describe a simple method of secondary repair

Secondary Repair Under local anesthesia, the divided duct is exposed after excision of the former scar The blunt end of a probe is inserted from the mouth through the papilla into the peripheral end of the duct and escapes through the wound of the cheek a strand of cotton (No 10) or heavy silk is tied as a double loop to the probe and both are with drawn through the mouth The patient is given a few drops of lemon juice to stimulate the salivary flow this facilitates identification of the proximal end of the severed duct The two ends of the cotton or silk strand are threaded through a long curved Mayo needle. The needle is passed backward with the blunt end first into the proximal duct With gentle manipulation the needle is forced through the parotid gland to the skin A tiny nick is made in the skin and the thread is carried through A small square of rubber sheeting is threaded on each end of the thread and this is followed by application of a lead shot on top of

loss of response distal to the injury is complete, in compression, the loss may be incomplete, particularly if the site of the lesion is in the soft parts and not in the bony canal with its unyielding wall The operation should be carried out as soon as the diagnosis is made

Decompression If the lesion appears to be outside the bony canal—that is beyond the foramen stylomastoideum—the nerve is exposed at its exit from the foramen, following the posterior belly of the digastric muscle The nerve is carefully dissected free until one finds the lesion, which may be located posterior to, within, or anterior to the parotid gland The nerve is now decompressed by removing the compressing cause and slitting the sheath of the nerve to gain further relief from pressure If the site of the pressure appears to be in the bony canal, the canal is opened by a mastoid operation, during which the descending and horizontal portion of the fallopian aqueduct is defined and opened The exit of the facial nerve at the foramen stylomastoideum serves as a guide Such an operation should be performed only by a surgeon competent in this particular field The pressure is released by removing the compressing cause and slitting the sheath of the nerve

Nerve Suture: If the facial nerve is severed, it should be sutured as soon as possible, unless the accident has occurred under septic conditions It should be remembered that the distal end of the severed nerve ceases to respond to the faradic current only after forty-eight hours Thus, location of the distal end by use of the faradic current is greatly facilitated during this period The severed ends are approximated and held accurately together by suturing the nerve sheath with finest silk, unless the severance is in the bony canal (see following paragraph). Even small gaps may be closed by direct nerve suture, rerouting the nerve along a shorter course (Bunnell)

Nerve-Grafting· If loss of substance has occurred (crushing injury) or is to be anticipated (considerable extent of compression), bridging of the defect with an autogenous nerve graft is indicated (for technic, see p 55) If the lesion is in the bony canal, the canal is opened, as just described, and the nerve is followed along its course, after identification of the lesion, the nerve is resected with a sharp knife until normal nerve fasciculi are exposed The nerve graft is fitted accurately in place, it does not require suturing, since the body fluid, serum, and blood clots anchor the graft in place Ballance and Duel cover the grafted area with pure gold leaf (22½ carat) for protection, then follow with a piece of gauze soaked in isotonic saline solution This dressing is left undisturbed for at least two weeks, from then on it is changed daily After complete healing, one should massage the paralyzed muscles daily and stimulate

membrane The wound is closed in layers A similar procedure but without the disk of skin is possible for internal fistulas

If the papilla of the duct in the mouth is destroyed or obliterated and the central end of the duct is too short to permit rerouting into the mouth plastic elongation of the duct becomes necessary

Technic (Küttner) (Fig 56) The central part of the duct is dissected free for a short distance The incision through skin and subcutaneous tissue and fascia is now led forward beyond the anterior border of the masseter muscle Through an opening in the buccinator muscles the mucous membrane is exposed It is incised so that a tonguelike flap is tubed by proper suturing and connected with the central end of the duct after temporary insertion of a urethral catheter as a dowel Closure of the opening in the mucous membrane is not difficult.

If it is impossible to restore the continuity of the duct and the fistula persists Frey s method of closure may be helpful This involves daily injections into the fistula of 0 3 cc. of a 10 per cent solution of sodium morrhuate

Deformities

PALSY FROM PERIPHERAL LESION OF FACIAL NERVE

A peripheral lesion of the facial nerve can occur with or without interruption of the continuity of the nerve substance. In the absence of nerve interruption it may be due to cold (toxic neuritis primary or idiopathic paralysis Bell s palsy) to inflammation of the surroundings or to pressure

Complete or incomplete paralysis of one side of the face is the most outspoken symptom The treatment is either conservative or surgical

Conservative Treatment. In all cases where there is no evidence of severance or compression of the nerve conservative treatment is indicated at least for several months daily massage and stimulation with the galvanic current for a few minutes three times weekly If however the faradic response is still absent or does not recur after five or six months surgery is indicated

Surgical Treatment

Surgical treatment is required if the paralysis of the facial nerve appears to be the result of pressure or of severance of the nerve The presence or absence of response to the faradic current is of diagnostic and locating value In compression the loss of response to faradic stimulation distal to the lesion is—as a rule—gradual while in severance the loss occurs after forty-eight hours. Furthermore in complete severance the

muscle implantations in markedly sagging palsies do not supply sufficient static support Whatever method of reanimation (dynamic support) that one may, however, choose, one should bear in mind that it takes effort and patience to dissociate the patient's function of chewing from that of smiling and to overcome some involuntary mouth movements when the patient is eating

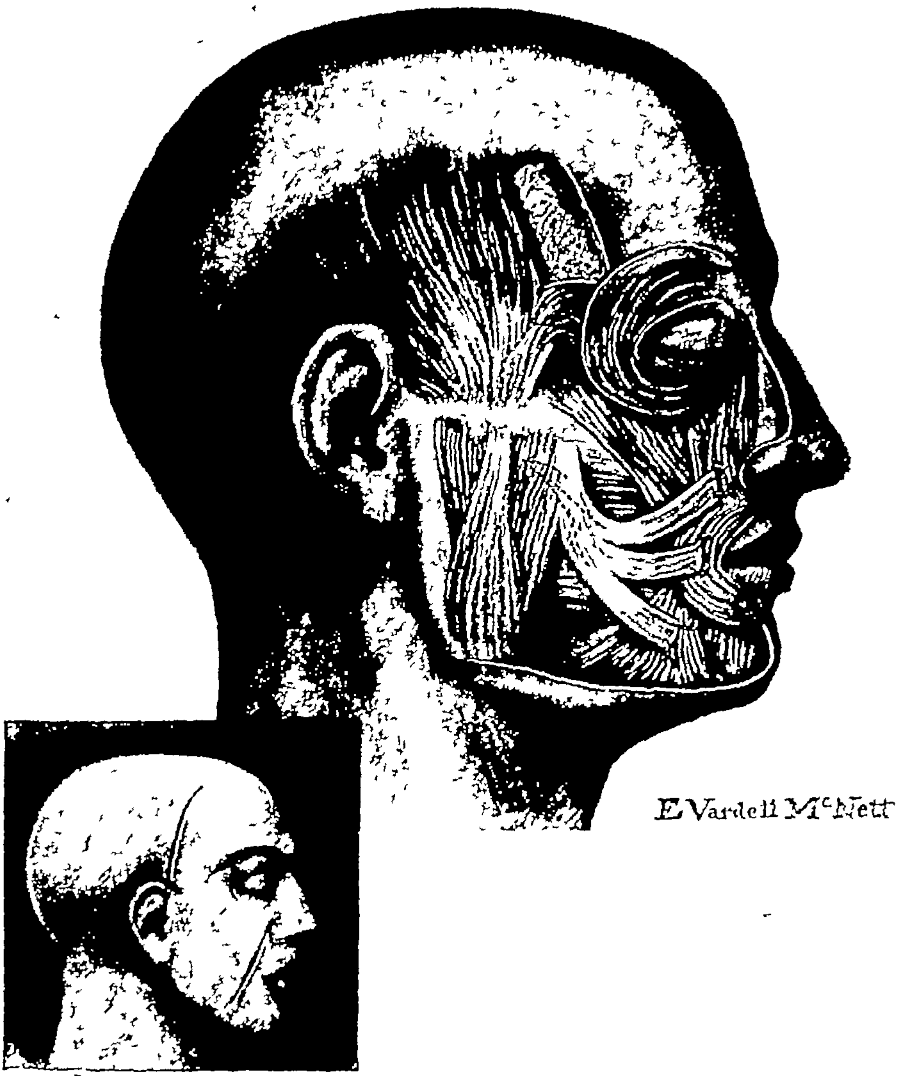

Fig 57 Operation for dynamic support (muscular neurotization) in facial paralysis (Lexer) From two functioning muscles, musculus temporalis and musculus masseter, muscle flaps are separated and brought in contact with paralyzed muscles Note that flaps are made parallel to direction of nerve trunk Inset depicts incisions (E Lexer Die Gesamte Wiederherstellungschirugie J A Barth, Leipzig)

Static support is the simpler procedure By means of fascia-lata loops or wire slings, the sagging tissues around the mouth, nose, and eye are fixed to the temporal fascia or the zygoma Although preceded by others in the use of fascia grafts in facial palsy, Blair deserves credit for having

them with the galvanic current for a few minutes three times weekly A return of active function of the muscles may not occur for from three to six months after the operation

Facial Nerve Anastomosis Anastomosis of the facial nerve with another healthy motor cranial nerve is seldom employed and should only be performed by a competent neurosurgeon

Suspension of Paralyzed Muscles The object of the operation is to fix mechanically the sagging tissue of one paralyzed side and to counter act overactivity of the unparalyzed side This operation is indicated if suturing of nerves or nerve-grafting is contraindicated or has failed. Sus pension of the paralyzed muscles is also advisable after nerve anastomosis to prevent overstretching of the paralyzed muscles by their opponents while nerve and muscles are regenerating The suspension is achieved either by static fixation or by reanimation (dynamic support)

A *dynamic support* is the ideal one and should be carried out when ever possible i e in the younger patients in whom intelligent coopera tion can be expected Reanimation is performed in one of two ways either by implantation of flaps of functioning muscles (musculus masseter and temporalis) into the paralyzed muscles or by transmitting the con tractile power of a functioning muscle to the paralyzed muscles via a fascia graft or by other means It must be borne in mind that the dynamic support must be a static support i e. must support the para lyzed side while the face is in repose Muscle-implantation operations (Lexer Rosenthal Sheehan and others) may fail in this respect since their success depends mainly on regeneration of the paralyzed muscles from the transplanted unparalyzed muscles by so-called neurotization (Erlacher) Hence reanimation of the paralyzed muscles via fascia-graft connection with functioning muscles may be the better procedure as devised by Brown and by McLaughlin The author has had personal experience with Brown s method but is not in a position to judge the merits of McLaughlin s procedure which is said to achieve a greater degree of reanimation and is enthusiastically supported by Winkler and others The author has also had opportunity to evaluate some of Lexer s patients in whom functioning muscle flaps had been transplanted Lexer of Germany who is credited for being the first (1908) to introduce this principle of reanimation in facial palsy reported on follow up examina tions of thirty two patients of whom ten were markedly improved twelve moderately improved and the remainder unimproved The unimproved cases were mostly among those whose palsy had existed two years or longer before the operation Others have made similar observations (Rosenthal Sheehan Neal Owens Maurer) The author concludes that

After-treatment is similar to that described on p 175 However, it should be supported by mild massage and galvanization after healing has taken place

Technic (Brown) (Fig 58, Case 15, p 866) A long strip of fascia lata is removed with a fascia-stripper (see p 27) or from a long incision at the lateral surface of the thigh, this fascia is to be divided into strips, each

Fig 58 Corrective operation for facial palsy by suspension of paralyzed muscles with fascial grafts (After J B Brown Ann Surg)

having a width of 1 cm (about 3/8 inch) A slightly curved incision is made in the hairbearing temporal region, about 6 cm (2 3/8 inches) long, and the temporal fascia is exposed by retraction A long needle, such as pictured in Fig 59, is pushed from this wound through the subcutaneous tissue of the face and the upper lip until its tip can be felt a little beyond the philtrum on the sound side Through a stab hole in this region, one end of the fascial strip is threaded in the needle, the needle is withdrawn, and the fascial strip is disengaged The needle is carried again from the temporal wound, but through a different subcutaneous canal, until it emerges again at the philtrum wound The other free end of the fascia

popularized the method He takes fascial strips from the iliotibial band. One end is fixed to the temporal fascia or to the fascia superficial to the parotid gland while the other engages the tissue to which the paralyzed muscles or group of muscles is attached For instance fascial strips that substitute for the orbicularis oris and buccinator muscles should well engage the fibers of the unparalyzed half of the orbicularis muscles both in the upper and lower lips and be fixed laterally to the fascia in front of the ear Brown modified this method by anchoring the fascial loops not only into the temporal fascia but also into the temporal muscle thus stabilizing and suspending the paralyzed side as well as transmitting some of the action of the temporal muscle, hence making this method static as well as dynamic

Technic of Dynamic Support (after Lexer) (Fig 57) From the two functioning muscles—musculus temporalis and musculus masseter supplied by the nervus trigeminus—muscle flaps are separated and rotated in such a way that they can be brought in contact with the paralyzed muscles For formation of the masseter flap the incision runs along the nasolabial fold which in most cases is effaced hence it is important to make the incision symmetrically with the fold of the sound side The anterior border of the musculus masseter which is found posterior to the fat pad of the cheek is dissected free from the lateral wound edge until a flap can be separated in such a way that the base of the pedicle comes to lie toward the zygoma Care should be taken not to injure Stensen s duct. The arteria maxillaris externa may be ligated The peripheral end of the flap is divided in two or preferably in three portions which are sutured upon the musculus orbicularis oris above and below the commissure of the mouth and the musculus quadratus labii superioris. These muscles are exposed from the anterior wound edge These muscle flaps should be under moderate tension after the suture resulting in some overcorrection of the paralyzed side

Maurer found it easier to expose the masseter muscle from an incision along and just below its mandibular insertion The masseter flap is severed from the mandible and by retraction of the upper wound edge mobilized to about 2 5 cm (1 inch) from the zygomatic arch A curved incision is then made 1 cm (⅜ inch) lateral to the commissure of the mouth the masseter flap which Maurer does not split, is tunneled into this incision and sutured upon the musculus orbicularis oris musculus quadratus labii and musculus zygomaticus

Lexer also devised a dynamic support of the paralyzed musculus orbicularis oculi by means of flaps from the temporal muscle as demonstrated in Fig 57 A lateral tarsorrhaphy as described on p 376 is simpler and perhaps more effective for lessening the lagophthalmos

zygomaticus major In this way, the operation is purely static, the advantage lies in firmer fixation and shorter fascial strips, thus, they are less apt to stretch This operation is indicated for patients incapable of the intelligent cooperation that is required in dynamic support

Technic of Static Support (after McLaughlin) (Fig 60) Three tiny incisions are made one in the upper lip just within the philtrum, one in

Fig 60 Static support of paralyzed muscles from facial palsy From three tiny incisions a double loop of fascia lata strips is laid around the paralyzed muscles of the mouth, a second fascia strip is looped around the first loop and—from a separate incision—drawn through a drill hole of the malar bone (McLaughlin, C R Plast & Reconstruct Surg)

the lower lip at about the midline, and one in the lateral side of the mouth on the paralyzed side Two 0 6-cm (¼-inch) strips of fascia are removed from fascia lata, one 17 7 cm (7 inches) and the other 10 2 cm (4 inches) long With the fascia-carrier (Fig 59), the longer of these loops is carried in a figure-of-eight fashion so that it reaches the unparalyzed portion of the orbicularis muscle just beyond the midline in both the upper and lower lips The two ends are then brought out through the incision lateral to the mouth and are tied—care being taken not to stenose the mouth—and sutured together with silk The second strip is looped around the double loop at the commissure of the mouth The

is now withdrawn so that a loop is formed at the philtrum A second loop of fascia is placed around the angle of the mouth Additional loops to the ala and across the lower lip may be necessary in heavily drooped faces When all loops are in place one strand of each is carried through the temporal fascia all the way down through the muscle and out again through the fascia for a distance of 1 or 2 cm (3/8 or 13/10 inch) The loops are then pulled tight to overcorrect the paralyzed side of the face the first part of a surgeon s knot is put in the loops and they are clamped with two mosquito forceps Then fixation is firmly effected with three or four fine silk sutures put through the loops and tied around them Brown emphasizes that an effort should be made to get a secure hold on the muscle in a region where there is the most movement, and this is close to the attachment of the coronoid process

Fig. 59: Fascia-carrier needle used for insertion of fascial strips.

If the eyelids are paralyzed a lateral tarsorrhaphy (p 376) is the simplest procedure to lessen the lagophthalmos

After Treatment A firm pressure dressing is applied Speaking and chewing should be prohibited for one week. The patient should be on a liquid high caloric diet fed through a Jutte tube The dressing is changed after one week and the operated side of the face is supported for about three weeks with adhesive strips running from the side of the mouth to the temporal region Later on the patient should train his facial movements to separate the functions of chewing and smiling and he should particularly avoid overactivity of the sound side. This training is best done before a mirror In cases of long-standing facial palsy the skin has stretched to such an extent that excision may be needed after the suspension operation to avoid unpleasant wrinkles For technic, see p 181

McLaughlin devised a shorter route for anchoring the suspending fascial strips. He uses the zygoma as the point of fixation He considers it the best point since it lies nearer the mouth and the fascia sling follows the most important of the paralyzed mouth-suspending muscles the

If the eyelids are paralyzed, fascial support of the lower lids is recommended but is seldom satisfactory The simplest procedure to lessen the lagophthalmos is lateral tarsorrhaphy (see p 376) This narrows the palpebral fissure, reapplies the lower lid against the eyeball, and relieves the epiphora

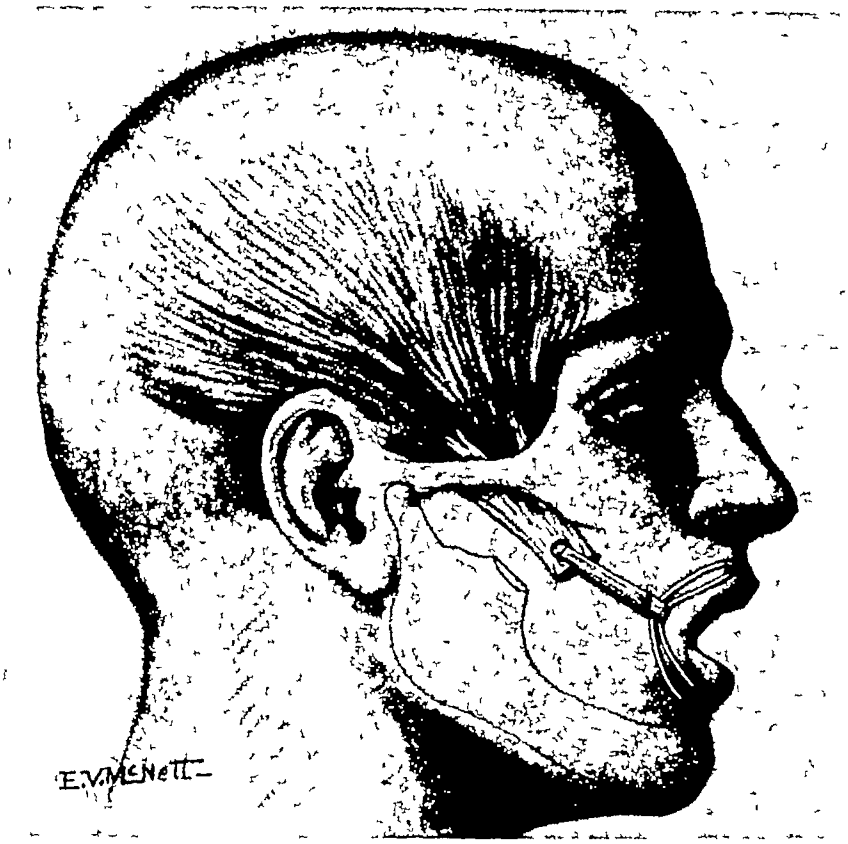

Fig 61 Dynamic support of paralyzed muscles from facial palsy A double fascia lata loop laid around the paralyzed muscles of the mouth (compare with Fig 60) is drawn up by another fascial loop to the attachment of the unparalyzed temporal muscle at the severed coronoid process (McLaughlin, C R Plast & Reconstruct Surg)

After-Treatment See p 175

In ptosis of the upper lids due to paralysis of the frontalis muscle, McLaughlin advises excision of an elliptiform piece of skin and frontalis muscle from just above the eyebrow After the wound is closed, the lid becomes elevated

PARALYSIS OF MUSCLES OF CHIN

Paralysis of the depressor muscles of the chin is not infrequent It occurs particularly after surgery for removal of the cervical lymph nodes or tumors of the parotid region When the patient is relaxed, the lip appears normal, but when he talks, the asymmetry becomes evident by the contraction toward the unaffected side In these cases, fascial suspen-

malar bone is exposed through a separate incision which crosses the malar bone obliquely from its median upper portion laterally and down ward. After stripping a small area of periosteum a hole is made with a dental drill and enlarged sufficiently to admit the fascial strip using a wire noose, one end of the fascia lata loop which had been carried with the fascial-stripper to the malar bone is drawn through this hole The other end is then brought up but not through the hole and the two ends are twisted together and sutured The twist should be made so that over correction is achieved since the muscles on the unparalyzed side are without tone under anesthesia.

If the eyelids are paralyzed, a lateral tarsorrhaphy (p 376) is the simplest procedure to lessen the lagophthalmos.

After Treatment See p 175

McLaughlin also devised an operation for dynamic support which is enthusiastically accepted by Winkler and others Ideal as it is, it requires intelligent cooperation of the patient however and may be best suited for the younger ones If dynamic support is chosen the temporal muscle together with its insertion point the coronoid process is selected as a motor and the contractile power of the muscle is transferred to the para lyzed muscles via fascial strips

Technic of Dynamic Support (after McLaughlin) (Fig 61) As in his former method (p 176) a fascial strip 17 7 cm (7 inches) long and 0 6 cm. (¼ inch) wide is led in a figure-of-eight fashion through the paralyzed half of the orbicularis muscle of the mouth and the two ends are tied and sutured together The operation is then continued intra orally to expose the coronoid process The jaws are widely separated and kept open with a cleft palate gag It is now easy to palpate the coronoid process An incision is made through the mucous membrane over the coronoid process After the necessary dissection the upper part of the process is exposed and a hole is drilled into bone near the apex A wire loop is passed through this hole and the coronoid is divided a little below with a small saw or chisel The wire loop is used to draw a fascia lata strip 0 6 cm. (¼ inch) wide and 10.2 cm (4 inches) long through the hole Both ends of the fascia are then brought through a single subcu taneous tunnel down to the figure-of-eight at the angle of the mouth This is facilitated by leading the fascia-carrier from the incision lateral to the mouth toward the oral incision in the mouth The fascial strip should be pulled in such a direction as to fall in a direct line and to run easily in the soft tissue The fascial strips are then looped around the figure-of-eight fascial loop and sutured together Again an overcorrection should be produced

sion and muscle transplantation are not successful Marino advises neurectomy of the ramus marginalis mandibuli of the opposite side This is a simple and effective procedure Before this operation is recommended, however one should ensure the result by injecting a few cubic centimeters of 2 per cent procaine near the angle of the mandible on the unparalyzed side to block the mandibular nerve If the reaction is satisfactory operation is indicated

Technic: The operation is performed under general anesthesia. A small incision is made about 1 cm ($^3/_{16}$ inch) behind the angle of the mandible of the unparalyzed side. The ramus marginalis of the facial nerve is located This may be facilitated by using a cortical stimulator with a bipolar electrode. After the nerve is completely dissected free the stimulator is applied again to determine exactly the group of muscles supplied by the exposed nerve. This will avoid damage to the buccal branches it will also ascertain whether there is only one or several branches leading to the depressor muscle of the lower lip All of them must be resected to ensure success Neurectomy is performed A few millimeters of the nerve is removed to prevent regeneration The small wound is closed with fine sutures

DEPRESSIONS RESULTING FROM SKELETAL INJURIES OR DESTRUCTION

These are due to fractures or destruction of the skeletal parts In case of a *fracture,* reduction and retention of the reduced fragments (zygomatic arch etc.) will correct the deformity in the majority of cases (see p 454) Depressions resulting from bone *destruction* can be corrected by transplantation of dermal fat cartilage, or bone grafts depending upon the depth and location of the depression If the depression is the result of an *infection* the corrective operation should be delayed until at least three months has elapsed after closure of the last fistula and antibiotics should be administered preoperatively and postoperatively Any broad scar should be corrected first by skin-sliding or by skin flaps so that the involved area is covered with normal skin As far as the filling material goes dermal or derma fat grafts are suitable for shallow depressions (Case 12 p. 861) For *deeper depressions* however particularly those requiring rigid support bone grafts (Lexer Kazanjian Sheehan and others) or cartilage grafts, solid or diced (Peer) should be chosen Diced cancellous bone grafts from the *ilium* are also recommended (Mowlem Macomber) Converse inserts bone grafts through the mouth to overcome depressions of the cheek The danger of infection seems to be minimal since the advent of antibiotics. In *large defects of the*

and hospitalization It is apparent that the elastic facial skin, under the influence of the mimic muscles, cannot remain smooth after removal of strips of skin alone Such a procedure is of only temporary success, unless the skin is widely undermined toward the face to cause broad adhesions with the underlying inelastic fascia, and is firmly anchored to fascia or periosteum.

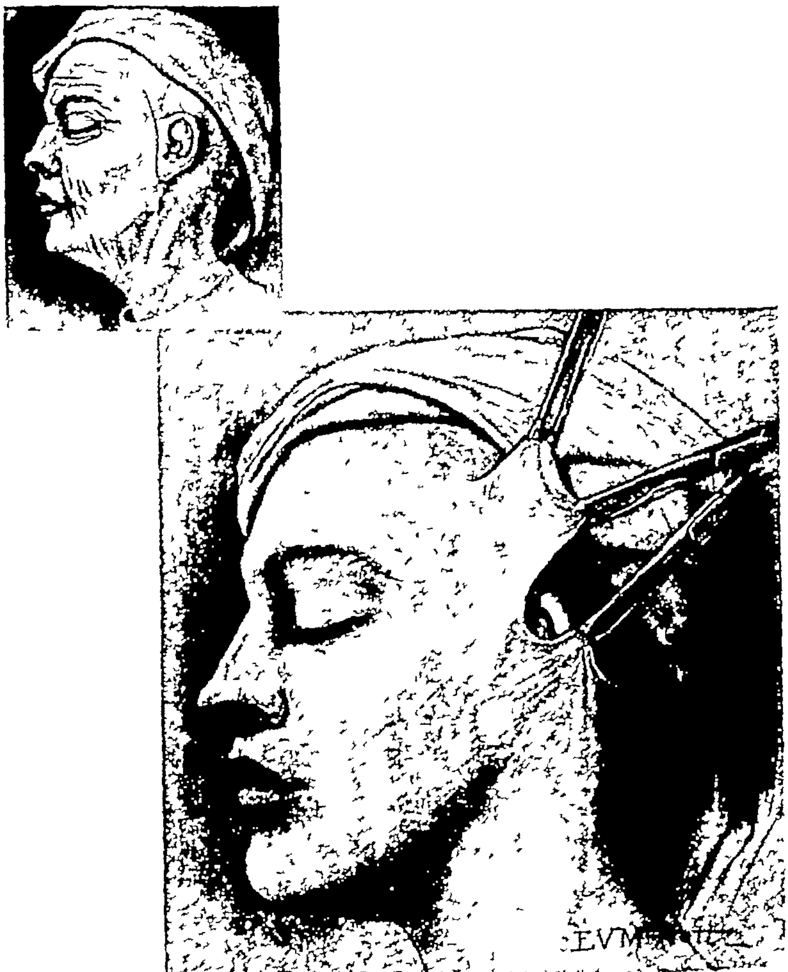

Fig 62, *a* Correction of facial wrinkles from an incision as outlined in insert After wide undermining of facial and cervical skin the loose skin is pulled backward over the ear

The most conspicuous wrinkles which need correction are the deep groove of the nasolabial fold, often combined with a groove in front of the masseter muscle, longitudinal folds of the anterior cervical skin, the wrinkles around the eye, and the transverse or longitudinal wrinkles of the forehead Either all these wrinkles may be present or only certain groups of them If they are all present, the operation should be performed in two stages. The correction of the wrinkles around the eye and of the longitudinal folds of the forehead should be the second stage of the performance

should be limited to those compartments only This has the advantage—as Kazanjian and Sturgis pointed out—that if degeneration or infection of the graft should occur in one compartment the others would not necessarily be involved The undermining of the skin is done bluntly with a pair of curved scissors along the superficial fascia Then follows hemostasis by packing the different compartments with gauze soaked in isotonic saline solution

Selection of Graft Dermal grafts and dermis fat tissue grafts are available Dermal grafts are used only in regions of slight depression around the orbit or in the temple region for instance. For regions with deeper depressions a composite graft consisting of derma and fat (removed from the abdominal wall) is used

Insertion of Grafts After removal of the packing a temporary silk suture is passed through that part of the graft which is to become the upper pole with a long straight needle both silk threads are passed through the highest point of each compartment to the outside For proper passing of the needle see p 184 By pulling at the threads one inserts the grafts in each compartment without the use of traumatizing instruments If composite derma fat grafts are used the dermal portion should come to lie upon the lateral part of the cavity The suture is then tied over a small gauze pad and the wounds are closed

After Treatment The whole area is kept under moderate pressure The patient is prevented from chewing and speaking for one week He is kept on a liquid diet during this time In case of shrinkage of one or more grafts subsequent operations may become necessary

DEFORMITY FROM HYPERTROPHY OF MASSETER MUSCLE

Benign hypertrophy of the masseter muscle is a rare condition and is described here only in brief For details the reader is referred to publications of Adams and Masters et al This condition which is a soft ill defined contractile mass within the masseter muscle may be unilateral or bilateral It can be corrected readily according to Adams technic by resection of the medial part of the hypertrophied muscle together with any abnormal bony-spur formation at the angle of the mandible which often accompanies the masseteric hypertrophy

CORRECTION OF FACIAL WRINKLES

This may be necessary for economic as well as purely cosmetic and psychic reasons This type of operation has been commercially exploited by charlatans well advertised by them as a minor but effective procedure. It should be understood that to make the procedure effective the operation becomes a major procedure requiring careful selection of the patient

and held in a similar way The degree of lift is now checked, and, if found correct, the skin of the anterior flap is excised along and at the level of the posterior wound edge The same is done with the posterior flap The newly created wound edge is fastened with subcutaneous oblique (advancing type) cotton sutures to the temporal fascia, the fascia in front of the ear, and the periosteum of the mastoid region Adjustments to achieve a smooth coaptation of the skin edges behind the ear are usually necessary, and can be achieved by extending the posterior incision farther backward and downward The skin edges in front of the ear should be free of tension, most of the tension should be in back The wound is sutured with fine silk or nylon, and a drain inserted in the upper anterior and lower posterior edges

If the transverse frown wrinkles need correction, they are corrected from a transverse incision parallel to and within the frontal hairline The following procedures are similar to the ones described above As a rule, the area posterior to the incision becomes asensitive for several months

After-Treatment: A heavily padded pressure dressing is applied for about three days, the skin sutures and drains are then removed, and the incision is covered with a layer of collodion

If the longitudinal forehead (frown) wrinkles and the wrinkles around the eyes and of the eyelids are conspicuous, they are corrected in the same or another stage (two or three weeks later) Correction of eyelid wrinkles is described on p 389 Correction of frown wrinkles is not satisfactory, and this should be pointed out to the patient They are best improved by the intracutaneous insertion of a strip of dermal graft

Technic. A small incision is made at the upper termination of the longitudinal frown wrinkle The skin is undermined along the wrinkle toward the eyebrows The undermining is done intracutaneously (not subcutaneously) The dermal graft (for its removal, see p 42) is inserted as follows A straight cutting-edge needle is clamped longitudinally within the branches of a mosquito hemostat The tip of the needle should not project The hemostat is passed through the skin tunnel When its blunt end has reached the blind end of the tunnel near the eyebrow, the hemostat is opened, and the needle is pushed through the skin One end of the derma graft is fastened to a silk suture, both silk strands are threaded through the eye of the straight needle, and by withdrawing the needle, the dermal graft is pulled into the canal The suture is tied loosely over a small gauze pad, the free end of the graft is shortened, and the small skin wound is closed over it The sutures, including the anchoring suture, are removed on the third postoperative day

Technic (Fig 62 *a, b*) The operation is performed under local or general anesthesia (The author prefers general anesthesia local anesthesia effaces the wrinkles and leaves the degree of correction to the imagination of the surgeon) An S-like incision is made this starts within the shaved hairline of the temporal region and extends downward along the anterior base of the ear it then curves around the

Fig. 62, *b*: After proper excision of redundant skin median wound edges are fastened with subcutaneous cotton sutures to fascia of lateral wound edges followed by closure of skin wound.

insertion of the ear lobule and is led obliquely upward into the hair line and curves again backward and downward just in front and along the hairline The median wound edge is dissected free from the underlying fascia for at least 2.5 cm (1 inch) at the cheek the zygoma must be reached and dissection is extended toward the mouth in this region the fascia is thin and likely to be penetrated this must be avoided to prevent injuries to the facial and trigeminal nerves and Stensen's duct the cervical skin is elevated from the platysma and along and posterior to the musculus sternocleidomastoid the tough fascial extensions in front of this muscle must be severed In front of this muscle the posterior auricular nerve should be exposed and safeguarded and in back care must be taken not to injure the nervus accessorius it is good to visualize it. After thorough hemostasis the loose anterior skin flap is pulled backward to overlap the posterior wound edge and held in this position with a few towel clips. The posterior skin flap is pulled upward and forward

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VIII

THE LIPS, CHIN, AND PALATE

Defects

WOUNDS OF LIPS

Wounds of the lips are treated like wounds elsewhere Unless the wound is grossly infected, however, it should be sutured primarily, regardless of the lapse of time Excision of the ragged wound edges should be made as sparingly as possible Whenever the full thickness of the lip, including the vermilion border, is severed, accurate suturing of the different layers is of the utmost importance. The first suture to be placed is through the mucocutaneous junction of the vermilion border Traction on this suture causes the other structures to fall in line Mucous membrane and muscle layer are sutured from the buccal side with an on-end mattress suture of cotton or silk through both layers, skin and vermilion borders are closed with silk or nylon No dressing is required The skin sutures are removed on the third day, the mucous-membrane-muscle sutures on the eighth day

DEFECTS OF VERMILION BORDER OF LIPS

These defects may include the partial or total length of the vermilion border, as well as varying widths of it If narrow strips are to be replaced, an adjacent mucosal flap, consisting of the entire oral length of the lower lip down to the gingival sulcus, should be mobilized and shifted forward to reach the external wound edge For larger defects, flaps from the opposing lip should be used Langenbeck's often-quoted method, as a rule, does not give the satisfactory cosmetic results which the classic illustrations make one believe But there are various other reliable methods available

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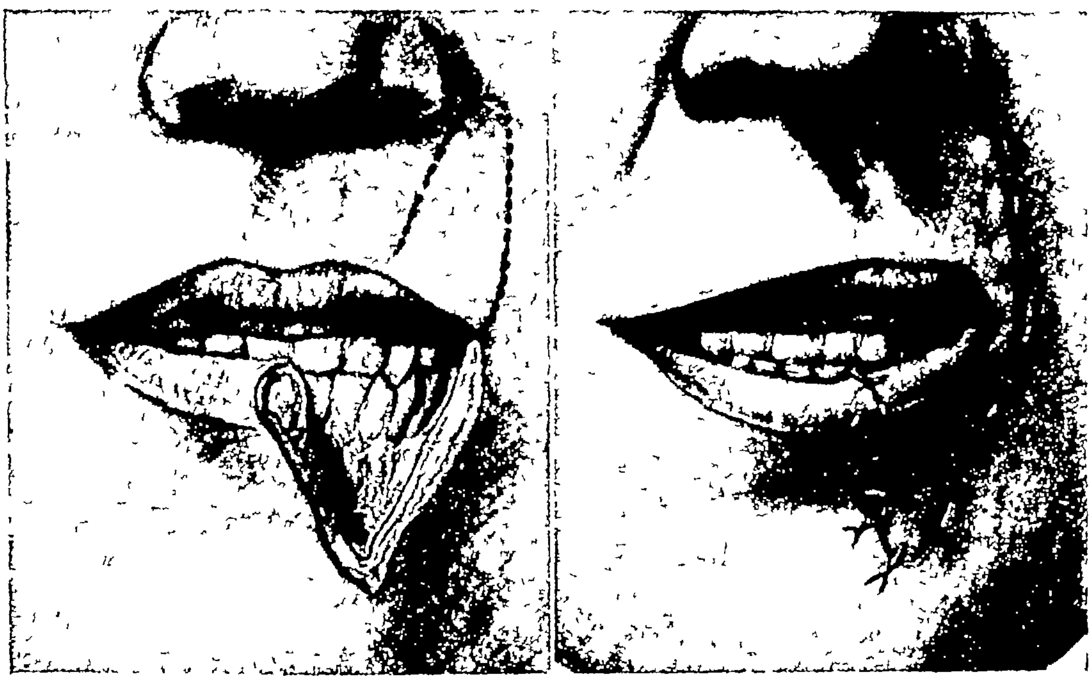
pedicled at one side of the vermilion border which contains the coronary artery The latter must be preserved since it is the only nutrient artery Estlander's original operation was devised for closure of triangular defects of the lower lip near the commissure of the mouth (Fig 65) The flap, consisting of the full thickness of upper lip and cheek, was rotated into the defect in such a way that the pedicle formed the new angle of the mouth This operation has been modified in many ways since Abbé used the same principle for closure of defects of the upper lip He also demonstrated that the method is useful for defects not including the commissure In such a case, the pedicle of the flap crosses the mouth and



a b

Fig 65, *a* Closure of triangular defect of lower lip with flap from upper lip in defects not larger than one half the width of lip Defect includes lower border of left angle of mouth To close defect, a vermilion-border-lined flap is rotated from upper lip and nasolabial region Pedicle of flap containing the coronary artery is to replace the commissures of mouth Flap should be made one half as wide as defect to shorten upper and lower lip proportionately (H May Ann Surg)

b. Flap is rotated into defect Secondary defect is closed by suturing wound edges together

has to be separated later (Fig 67, Case 20, p 873) Other modifications include those of Buck, Brown, Padgett, and Cannon

Technic (Estlander) Some of the different ways in which Estlander's principle can be used are outlined in Figs 65 to 68 (see also Case 20, p 873) Only a few important points for achieving a closure of the defect and a satisfactory cosmetic result need be emphasized The defect is made

Closure of Defects of Middle Section of Vermilion Border (Gillies-Lexer) The principle of this method is the formation of a mucous-membrane flap from the buccal side of the opposing lip the flap has its free border at the gingivolabial sulcus and is pedicled at the vermilion border The flap is hinged and is sutured into the defect immobiliza tion can be achieved with a Barton bandage The pedicle of the flap is severed after ten days, and pedicle and remainder of flap are adjusted in place

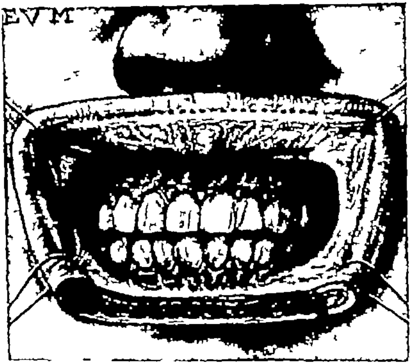


Fig. 63, *a* Closure of defect of entire length of vermilion border of lower lip with double-pedicle mucous-membrane muscle flap from upper lip (Af Schultén) Upper and lower lip are everted with traction sutures.

Closure of Vermilion Border Defects at and Adjacent to Angle of Mouth These defects are closed with mucous membrane flaps taken from the mucous membrane of the opposing lip they are pedicled and hinged in a way similar to that just described The form of the flap however must be triangular and the tip of the triangle is at the commis sure of the mouth while the base is the median border of the flap The after treatment is the same as that described for the foregoing method

Closure of Defects of Entire Length of Vermilion Border (Af Schultén) The principle is the formation and transplantation of a double pedicle mucous membrane-muscle flap from the opposing lip It is impor tant that the flap and its two pedicles which are situated near the angle of the mouth be thick enough to prevent necrosis (Fig 63*a* *b*)

After the flap is formed, the secondary defect is closed in layers as far as possible. The flap is now rotated into the defect. Mucous membrane, muscles, and skin are sutured separately. The side toward the pedicle and the corresponding side of the defect should be sutured first. Accurate

a *b*

c *d* *e*

Fig 67: In defects not including commissure, method of Fig 65 is applicable, pedicle of flap, however, crosses mouth and must be severed. After severance, flap and pedicle are adjusted in place with Z-type incisions as outlined in *a* and *c*, *d* and *e*.

approximation of the vermilion border of the flap and the defect's edge is necessary This may sometimes be difficult owing to difference in width, but then, at least, the mucocutaneous borders should be brought in alignment.

triangular The incisions are outlined with one of the aniline dyes The shape of the flap is now outlined opposite the defect within the nasolabial region The length (height) of the flap should be equal to that of the defect but the width of the flap should be only half that of the defect in order to shorten upper and lower lip proportionately In the majority

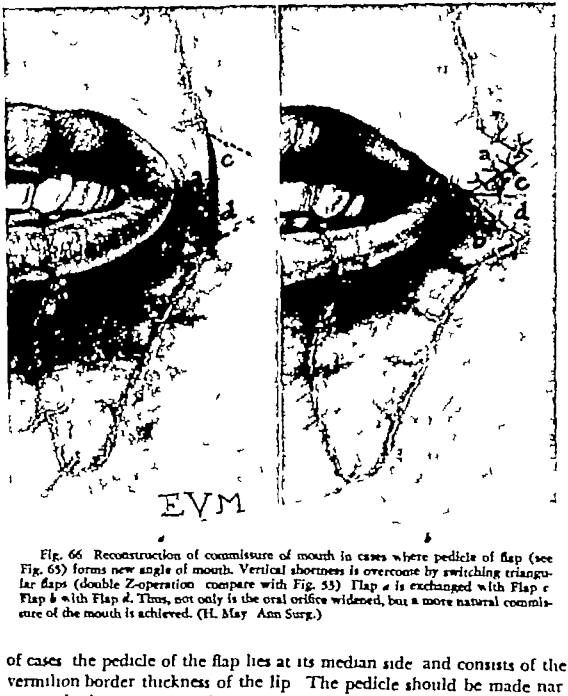


Fig. 66 Reconstruction of commissure of mouth in cases where pedicle of flap (see Fig. 65) forms new angle of mouth. Vertical shortness is overcome by switching triangular flaps (double Z-operation compare with Fig. 53) Flap *a* is exchanged with Flap *c* Flap *b* with Flap *d*. Thus, not only is the oral orifice widened, but a more natural commissure of the mouth is achieved. (H. May Ann Surg.)

of cases the pedicle of the flap lies at its median side and consists of the vermilion border thickness of the lip The pedicle should be made narrow to facilitate rotation but great care must be taken not to injure the coronary artery which runs within the vermilion

weeks after the first operation) as outlined in Fig 66. The principle is based on the switching of triangular flaps, as in Z-operations Thus not only is the oral orifice widened but a more natural commissure achieved (Case 21, p 874)

CROSSING OF MOUTH BY PEDICLE If the pedicle of the flap crosses the mouth, it must be severed (Fig 67, Case 20, p 873) This is done after three weeks After it is severed, it is adjusted into its original place, followed by adjustment of vermilion borders of flap and defect To facilitate adjustment, the author uses a Z type incision, as demonstrated in Fig 67, at the lower lip

Defects in Middle of Lower Lip: For defects in the middle of the lower lip, the procedure depicted in Fig 68 is recommended The commissure of the mouth can be reconstructed according to the method shown in Fig 66

Horizontal Defects

These defects may involve partial or full length of the lips Depending upon the size of the defect, flaps from the immediate neighborhood or from distant parts can be transplanted There are a number of procedures described which recommend the use of full-thickness cheek flaps The literature on this subject has been reviewed by Pierce and O'Connor Some of the procedures have never been practiced, and some of them give such poor cosmetic and functional results that they should be abandoned, not only from surgical practice, but also from textbooks Brun's operation is still highly recommended in some textbooks This method was tried by the author, but the result was far from that which the classic illustrations would lead one to expect There are a few excellent procedures available, however, which make use of flaps from the immediate neighborhood, consisting of skin and subcutaneous tissue only, and these are recommended whenever they are possible

Transplantation of Local Flaps *Technic (F Smith)* (Case 28, p 885) This reconstruction is completed in four stages, with proper intervening periods of time (Fig 69)

STAGE 1 COMPLETE DÉBRIDEMENT AND PREPARATION (IMMEDIATE) The management of the borders of the defect must anticipate reconstruction of the lip Flaps for a lining to replace the lost mucosa, for the outer skin covering, and for the vermilion margin, must be so planned that ample material enjoying an adequate blood supply is available

The blood supply of the lining flap, which will be reflected from the skin adjacent to the angle of the mouth, must come from the buccal mucosa and the muscle bordering the defect Consequently, the mucosa

After Treatment After the application of a dry dressing a Barton bandage may be used for one week and the patient fed a liquid diet.

OVERCOMING VERTICAL SHORTNESS In those cases in which the angle of the mouth was included in the defect and the pedicle of the flap forms the new commissure some vertical shortness is caused This consequently prevents the patient from opening the mouth fully To overcome the handicap the author recommends a procedure (to be performed three

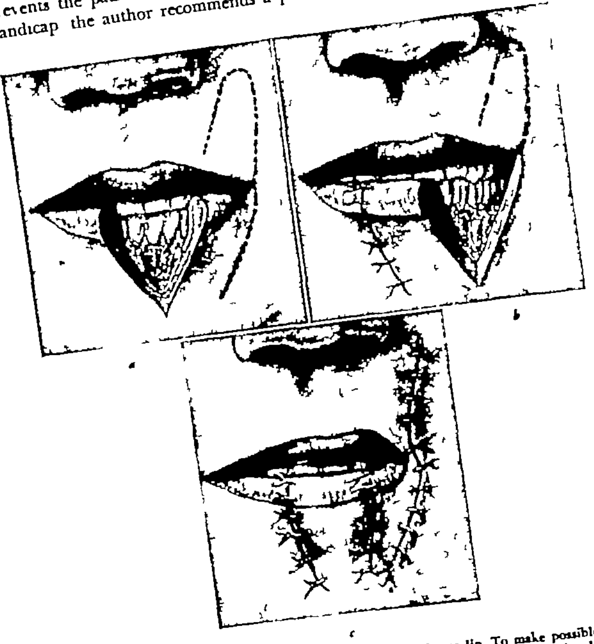


Fig. 68, *a* Triangular defect in middle portion of lower lip. To make possible the method shown in Fig. 65 defect must be transferred laterally This is achieved by closure of center defect with square flap. Outlines of this flap and flap of upper lip are illustrated. *b:* Square flap for closure of center defect is rotated into defect. This creates similar defect in lateral portion of lip. *c:* Flap from upper lip is rotated into lateral defect. Secondary defect of nasolabial region is closed (Buck) (H. May Ann Surg.)

It is sometimes advisable to utilize flaps from both sides of the mouth in the construction of an entire lip When this method is followed, a long covering flap and a shorter lining flap should be cut on one side and the reverse procedure practiced on the opposite side This will place the junction line of the covering flaps at a different place from that of the union of the lining flaps and will prevent a depressed, adherent scar line

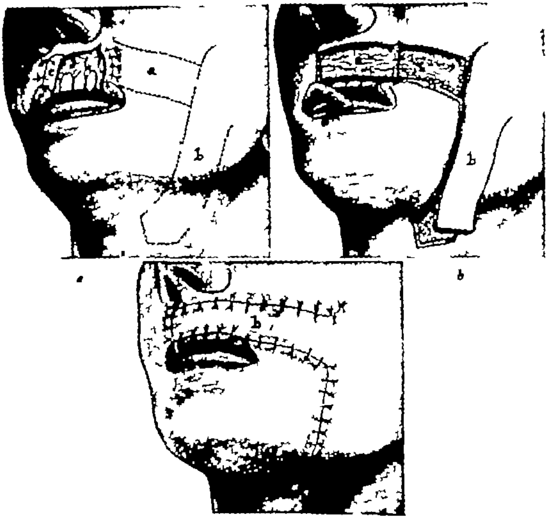
Fig 70 Outline of mucous membrane flap which had been rotated to replace lining and vermilion border of upper lip flap (compare with Fig 69 and Case 28, p 885)

The mucosa bordering the edge of the remnant of the lip is similarly undercut and sutured This mucosa will be utilized to form the vermilion border of the reconstructed portion of the lip (Fig 69, *a*, *b*, *c*) (This, however, is not necessary if the modification of the method described on p 199, Fig 70 is used) The remaining skin bordering the defect—chin or face and nose—is undercut and accurately approximated to the mucosal remnant along the buccal sulcus

STAGE 2 PREPARATION OF LINING (This step can be eliminated if the modification of the method described on p 199, Fig 70 is used) The purpose of this is to destroy hair follicles The operation is performed three weeks after Stage 1

The hair-bearing derma of Flap *a* (Fig 69, *a*) is excised like a full-thickness graft, one must be sure that all hair roots are removed, after thorough hemostasis by sponge pressure, the surface is covered with a thick, split skin graft from a hairless region of the arm or leg (donor area not to be shaved) The graft is covered with a strip of bismuth

on this edge must be undermined and accurately approximated to the skin with fine closely placed nylon sutures This produces a minimum of scar and a maximal blood supply This blood supply is usuall adequate but it can be guaranteed by outlining partially undercutting and again approximating this skin flap at this stage (Fig 69 *aa*)



a *b*

c

Fig. 69 *a*: Subtotal loss of upper lip replaced with flaps from immediate neighbor bood. Method of managing skin and mucous membrane on margins of defect outline of lining flap, *a* and covering flap, *b* for the reconstruction. F Smith: Manual of Standard Practice of Plastic and Maxillofacial Surgery W B. Saunders Co.)

b: Lining flap in situ, *a*; covering flap, *b* and mucocutaneous margin flap, *c* dissected.

c: Skin-covering flap rotated and sutured in position *b* mucocutaneous-border flap sutured in position, *c* skin defect in face and neck closed and sutured.

The covering flap (Fig. 69 *ab*) is outlined next It can be raised and sutured in its original location at this time if the blood supply is questionable The blood supply however is usually excellent.

reconstruction of portions of the bordering cheek, and is also useful for the reconstruction of the lower lip (Case 28, p 885) It saves Stage 2 (depilation of turnover flap) and the beginning of Stage 3 It is performed during the stage of corrections (see Stage 4); i e, at least thirty days after reconstruction of the lip, even if hair is growing on the oral side of the new lip

The hair-bearing skin on the oral side of the turnover flap, *a* (Fig 69, *a, a*), is removed as in Stage 2, the scar at the free edge of the lip (future site of vermilion border) is also excised A mucous-membrane flap (Fig 70) is made to be rotated according to the principle of Fig 35 The flap, of sufficient width to be removed below the opening of Stensen's duct, is made with parallel incisions in the lower buccal sulcus and higher in the buccal mucosa The pedicle of this flap is based adjacent to the angle of the mouth with a proper direction of incisions to permit its rotation and insure its blood supply, which is usually adequate under these circumstances This flap is rotated and sutured to the raw surface of the oral side of the new lip and to the edge of the outer wound to form a vermilion border

The defect in the buccal mucosa is easily closed by undercutting the borders and approximation

The same principle can be used for some of the larger defects of the lower lip excluding the chin The covering flaps will then, of course, be extended well below the mandible toward the neck In large defects this method may be performed bilaterally. The vermilion border, however, must then be furnished from the sound lip (see p 189) or by means of two buccal mucous-membrane flaps (see foregoing discussion)

Technic (Dieffenbach-Webster) (Fig 71) Jerome P Webster called attention to a method of upper-lip reconstruction which was devised by Dieffenbach over a century ago but which had been mentioned only sporadically in the literature and much less used It consists of a crescentic perialar cheek excision in preparation for advancement of a lip flap It can be used unilaterally or bilaterally, it also can be used in conjunction with other methods, such as the Estlander-Abbé flap from the lower lip It can be used for closure of defects as well as for correction of certain deformities of the upper lip, such as cicatricial changes

An incision is made in the alar fold along the base of the ala of the nose down to the periosteum It can if necessary be carried up above the ala along the nose This incision follows the ala on the base of the nostril to the defect The lip and cheek are then retracted upward, and the mucosa is incised along the upper labiogingival sulcus The muscles are stripped away from the attachment to the maxilla; this dissection is car-

tribromophenate (xeroform) gauze (p 34) and mechanics waste pressure is applied by tying the skin sutures which have been left long over the mechanics waste

STAGE 3 RECONSTRUCTION This is performed two weeks following Stage 2

The mucous membrane on the edge of the remnant of lip is removed between two parallel incisions 1 cm (⅜ inch) apart. (This step can be eliminated if the modification of the method described below Fig 70 is used) One incision is carried down its line of union with the skin and the other through the mucosa on the posterior surface of the lip The blood supply of the remnant is provided by the mucosa on the free margin of the lip and a broad portion of mucosa posteriorly Flap *c*, formed by the maneuvers just described is held on a sharp hook it will form the vermilion border of the reconstructed lip (Fig 69 *b*)

The skin flap *a* (in Fig 69 *a*, *b*) carrying underlying fat is turned from the face on a hinge and sutured to the incised margin of the mucosa on the posterior surface of the remnant of lip and along the superior border of the defect.

The covering flap *b* is incised and elevated with the underlying fat (Fig 69 *b*) The skin of the face on each side of the defect resulting from elevation of the covering flap *b* is freely undercut and approximated with nylon sutures Approximation of these skin edges adds two thirds of the width of the flap to its length This covering flap *b* (Fig 69 *b*, *c*) is rotated 90 degrees to cover the lip and the defect left by reflection of the lining flap *a* (Fig. 69 b) The opposing skin edges are sutured with nylon

The anterior edge of the mucosal flap *c* (Fig 69 *b*, *c*) is sutured to the free edge of the covering flap with nylon Its posterior edge is sutured to the lining flap

The suture lines about the mouth are painted with collodion and left exposed the wound at the neck is dressed

STAGE 4 CORRECTIONS The procedures are performed from thirty to sixty days after Stage 3

The teat created by the rotation of the covering flap *b* (Fig 69 *c*) is adjusted by removal of excess skin This should not be done sooner than the twelfth day because of possible damage to the blood supply of the transplanted flap prior to this time. Any other cosmetic defects are corrected at this period

Technic (Owens) A simpler and better method of lining the new lip and providing the vermilion border has been described by Neal Owens It is available only for cases involving the lip without required

wider than required) is outlined. The peripheral end of the flap which is to cover the defect is mobilized and separated from the galea aponeurotica The raw surface of the flap, as well as the opposite donor area, is skin-grafted with a thick split graft The the wound edges are sutured again.

After a week, the entire flap is raised by separating it from the galea aponeurotica. Bleeding is considerable, and is temporarily controlled by hemostats In the temporal region, the temporal fascia should be incised transversely and left attached to the pedicle to protect the trunk of the arteria temporalis As a rule, the flap can be transferred immediately, if there is evidence of discoloration, however, transfer should be delayed (p 70) If the flap can be transferred immediately, the peripheral end of the flap is sutured into the defect, as described previously The free borders of the flap are sutured together, similarly to forming a tube flap, so as to avoid raw surfaces The wound edges of the flap bed, to which the hemostats are still attached, are drawn together with long mattress sutures; these sutures also control the bleeding, so that the hemostats can be removed, and prevent the wound edges from retracting (compare with Fig 175*c*). The wound is covered with bismuth tribromophenate (xeroform) gauze

The mattress sutures are removed on the postoperative day The flap is gradually severed after two weeks, and the pedicle unfolded and returned to its original site. Further adjustments of the flap are the same as previously described Four weeks later, a new philtrum can be formed. A scalpel is introduced through a small incision in the middle of the vermilion border By leading the knife upward right beneath the skin and excising a flat section of tissue, one removes some of the hair roots, this causes growth of less hair in this region and a slight indentation At the same time, the skin lining of the flap may be replaced and a vermilion border formed according to the method described on p 199, Fig 70, whereby two such mucous-membrane flaps may be formed If only the vermilion border is to be replaced, the method on p 189 is applicable.

DEFECTS OF LOWER LIP AND CHIN WITHOUT LOSS OF BONE

Transplantation of Local Flaps: For closure of defects not larger than three quarters of the width of the lip and centrally located, Burow's and Bernard's methods are recommended (Fig 72, Cases 24, 25, pp 878, 880) (compare also with Fig 16)

Technic (Burow) To use this method, the defect must be triangular

ried up to the infraorbital foramen This procedure allows the cheek to be brought medially and in this advanced position the mucous membrane is closed with interrupted sutures along the labiogingival sulcus. The flap is then drawn forward and tentatively held in position by tight sutures A crescentic portion of perialar cheek tissue is then excised so that the skin edges of the cheek incision fit those of the ala without

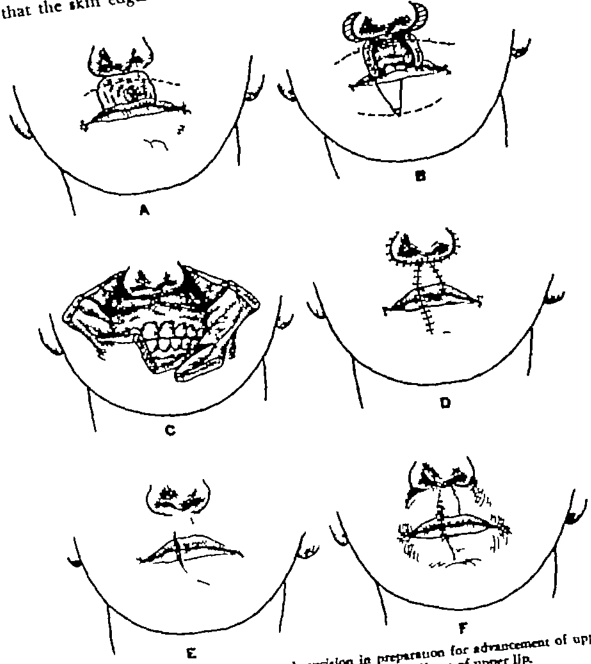
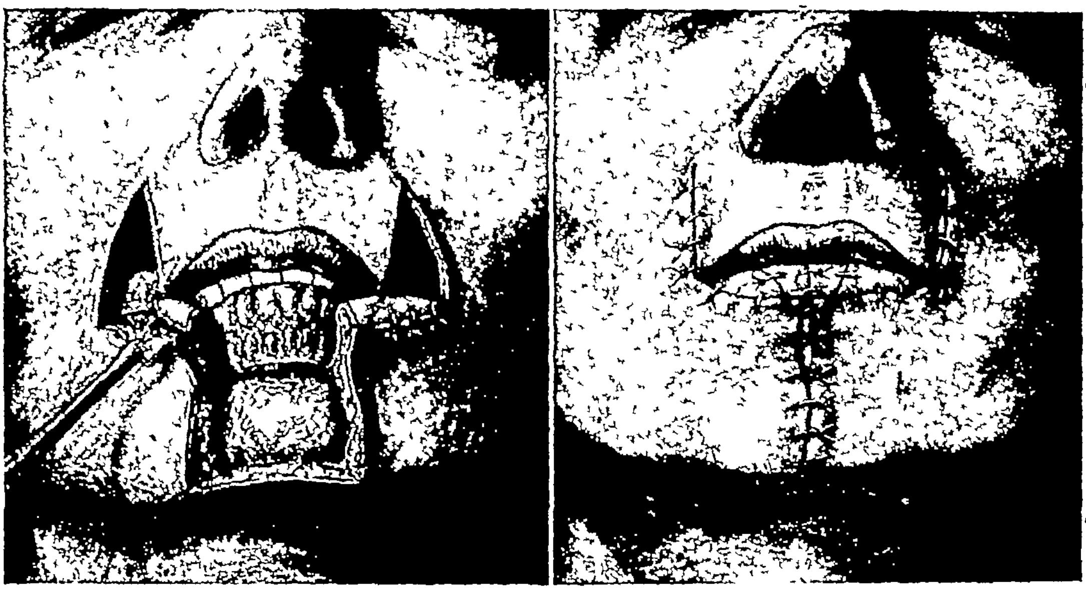


Fig. 71 Crescentic perialar cheek excision in preparation for advancement of upper lip flaps. *A*, Condition before excision of basal cell epithelioma of upper lip. *B*, Condition following excision of tumor bilateral excision of perialar cheek crescents and undermining of both cheeks. Upon drawing the wound edges together lip was found to be too tight. Hence an Estlander-Abbé flap from lower lip is added, B to F (J P Webster Plast. & Reconstruct. Surg.)

and (2) a more satisfactory adjustment of the mucous-membrane flap to the gradually disappearing original vermilion border. As a rule, a small triangle of skin needs to be removed at the corner of the mouth to make room for the tip of the mucous-membrane flaps (New and Figi). The flaps are now turned outward and sutured in place The lateral part, however, where the new vermilion border tapers off, may be too broad, owing to thickness of the cheek tissues, it should be thinned somewhat by excision of a wedge of subcutaneous and muscle tissue



a *b*

Fig 73 Bernard's method, modified by Martin, in closing square defects of lower lip and chin when defect is not larger than three quarters of lip Method similar to that of Fig 72

MOBILIZATION OF CHEEK FLAPS With an incision along the lower gingivobuccal sulcus, the mucous membrane is severed as far back as the last molar Then follows separation of the lateral cheek flaps from the outer surface of the horizontal rami of the mandible with the knife and with the aid of a periosteal elevator. The dissection should be carried back to the anterior border of the masseter muscle, and, if mobility of the flap is not sufficient, the masseter muscle may be separated from its insertion, care being taken not to injure the arteria maxillaris externa

CLOSURE OF DEFECTS The mobilized flaps are now pulled forward and anchored in this position to the gums by suturing the mucous membrane in the gingivobuccal sulcus Each suture should be placed obliquely so that it advances the flap forward The last suture should attach the mucous membrane of both sides in the midline of the mandible Then follows closure of the triangles in layers, starting with the mucosal side,

It is closed by shifting flaps from the immediate neighborhood into the defect after sacrificing two triangles of tissue in the nasolabial region (Fig 72)

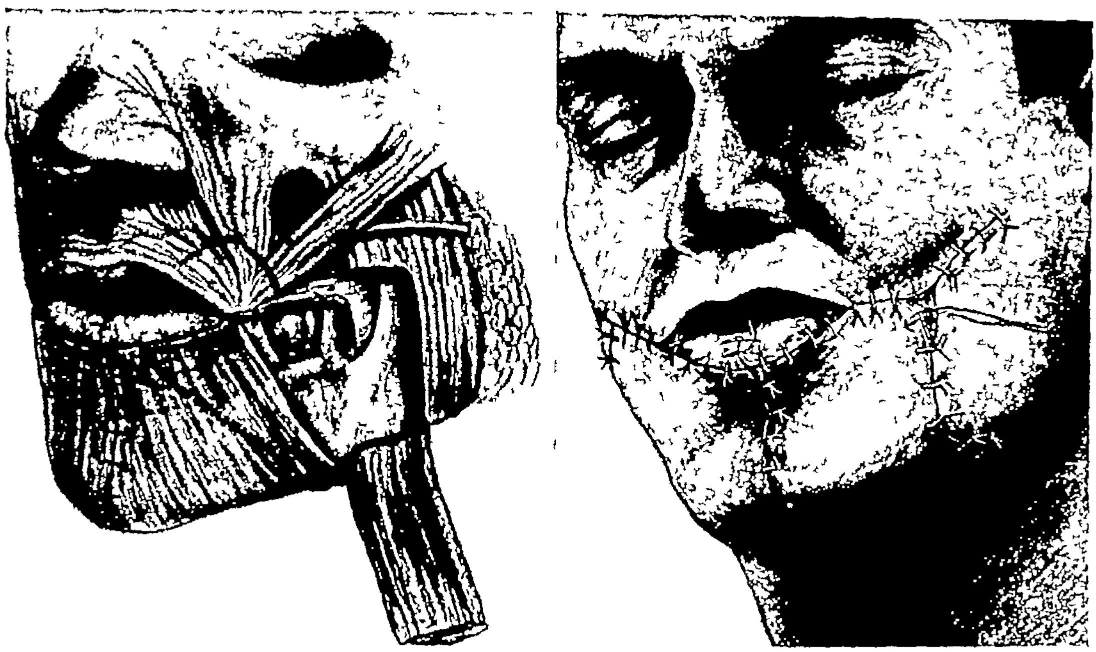
EXCISION OF LIP AND CHIN The lower lip and soft parts of the chin are excised in a heart-shaped rather than wedge-shaped piece (Dieffenbach) This results later in a more normal looking profile, with a dimple in the center of the chin

a b

Fig. 72, a Burow's method of closure of triangular defects of lower lip and chin when defect is not larger than three quarters the width of lip. Closure of defect by shifting tissue from immediate neighborhood into defect after sacrificing two triangles of tissue in nasolabial region. Excision of triangles should consist of skin and muscle only Incision of mucous-membrane flap of triangular defect is outlined. Turned outward, the mucous-membrane flaps lengthen vermilion border A small triangle of skin near corner of mouth must be removed for adjustment of mucous-membrane flap. Horizontal incision and excision of skin triangles below chin may facilitate shifting of main flaps and avoid pointing of chin. (H. May: Ann. Surg.)
b: After closure of primary and secondary defects.

EXCISION OF NASOLABIAL REGION The next step consists of excision of additional triangles in the nasolabial region They are marked out first with one of the aniline dyes The base of the triangle instead of lying in line with the vermilion border of the lower lip is slightly slanting laterally and upward and equals in length half the width of the defect The median side of the triangle follows or parallels the nasolabial fold so that after closure of the defects the suture line comes to lie within or parallel to the nasolabial fold The height of the triangle varies according to the length of its base Of these triangles only skin and muscles are excised The mucous membrane is separated as outlined in Fig 72 a If turned outward it will lengthen the vermilion border The purpose for shaping the small mucous membrane flaps as outlined in Fig 72 a, is twofold to provide (1) a gradual tapering off of the new vermilion border at the outer angles which are to form the new corner of the mouth

Technic (Dieffenbach) (Modification after Adelmann, Syzmanowski, May) For closure of defects of the entire lower lip and chin without loss of bone, a lined flap from distant parts of the body will be the method of choice in a number of cases, particularly for square, irregularly shaped defects If, however, the defect can be made triangular, transplantation of composite flaps from the immediate neighborhood may still be possible The writer recommends Dieffenbach's operation in such a case



c *d*

Fig 74, *c* Closure of triangular muscle and mucous-membrane defect in front of masseter muscle by mobilization of mucous membrane as far as possible and transplantation of flap consisting of lower anterior half of masseter muscle (Mobilization of flap is exaggerated in drawing for demonstration purposes)

d, Original and secondary defects are closed Horizontal incision and excision of skin triangularly below chin may facilitate shifting of main flaps and avoid pointing of chin (see Fig 72)

This method has been frequently criticized as being mutilating and extensive. The operation is extensive, but, correctly performed, it is not mutilating The writer has endeavored to improve the technic by slightly modifying it From cosmetic, functional, and economic standpoints, it is by far superior to distant flap transplantations The advantages are excision of the diseased part and closure of the defect in one sitting, thus short hospitalization, replacement of lost structures by similar structures, thus restoring original function and appearance (Fig 74, compare also with Fig 15) (Cases 23, 26, 27, 29, pp 877, 882, 884, 886)

The principle is based upon the creation of a triangular defect, which is closed by shifting two square flaps around one point of rotation

the next step is connecting the lateral edge of the new vermilion border to that of the upper lip then follows the vertical connection of both flaps in the midline in layers Some adjustment may be necessary at the bottom of the incision to avoid pointing of the chin (Fig 72 b) A drain is inserted in the lower corner of the vertical wound

VARIATIONS In defects less than half the length of the lip and particularly off-center defects only one triangle needs to be sacrificed and

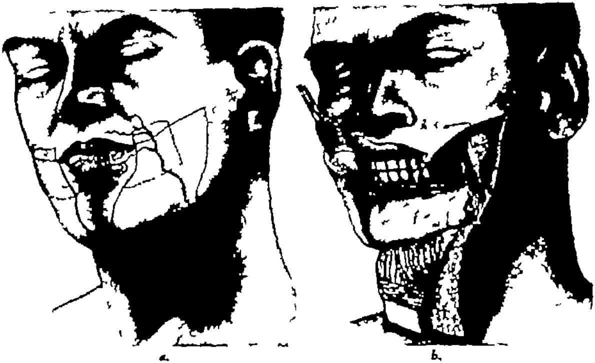


Fig. 74 a Modified Dieffenbach method for closure of large defects of lower lip and chin. Heart-shaped excision of lower lip and chin is outlined, as well as two square flaps which are to cover defect. Two small flaps at angle of mouth are preserved. Inside incisions for mobilization of flaps from mandible and from anterior border of masseter muscles are outlined by dotted lines, also small mucous-membrane flaps for formation of vermilion border

b Left flap is mobilized. Small mucous-membrane flap is sutured to outer edges of main flap. Right mucous-membrane flap for formation of vermilion border is being freed. (H May Surg., Gynec. & Obst.)

the cheek of the affected side mobilized One may be tempted to mobilize the other cheek also to facilitate closure but this may result in a deviation of the mouth as the author has once experienced. For other variations, see p 212 If dissection of the cervical glands is necessary it should be performed in a second stage.

Technic (Bernard) This operation is similar to Burow's with the exception that the defect is made square instead of triangular Martin improved the technic by modification. Fig 73 demonstrates the various steps.

MOBILIZATION OF FLAP The entire flap is now mobilized (Fig 74, *b*) Its lateral half is mobilized by outside incisions consisting of skin only Its median half is mobilized by inside incisions, comprising the entire thickness of the cheek The incisions for the lateral half penetrate not deeper than to the fascia parotideomasseterica, from which the lateral

Fig 75, *a* Large defect of lower lip and chin to be closed with tube flap from right pectoral region Peripheral end of flap is left untubed

half of the flap is separated The incisions for the median half begin with separation of the mucous membrane along its reflection at the mandible, and reach from the defect to the anterior border of the masseter muscle This incision includes the mucous membrane only The other inside incision, leading vertically upward, connects this latter point with the

from the immediate neighborhood into the defect (Figs 15 74) The incisions are outlined with one of the aniline dyes Before the anesthesia is administered the patient is requested to contract his masseter muscle its anterior border is marked out at its upper and lower insertion with a drop of methylene blue injected percutaneously Before operation the orifice of Stensen s duct is also marked with a drop of dye

EXCISION OF LIP AND CHIN The tumor together with the soft parts of the entire chin is excised in a heart-shaped, rather than a wedge-shaped piece (Dieffenbach) This results later in a more normal looking profile with a dimple in the center of the chin If possible the excision should not include the entire vermilion border at the commissure of the mouth The reconstruction of a labial commissure involves another problem In these cases, a very small flap of the vermilion at either side of the mouth is left as outlined in Fig 74 *a, b* The incisions on each side meet each other at a point below the center part of the mandible This point becomes the point of rotation around which two square flaps are turned from the immediate neighborhood

OUTLINES OF FLAPS AND FORMATION OF VERMILION BORDER For forming the left flap—likewise the right—the following incisions are made (Fig 74 *a*) From the left commissure an incision is carried obliquely upward to about 3 8 cm (1½ inches) in front of the tragus of the ear It is imperative that this incision be made obliquely *not* horizontally From there the incision is carried downward at an angle less than a right angle, ending below the mandible

The next step is the formation of the left half of the vermilion border From the angle of the mouth to the anterior border of the masseter muscle the incision includes skin and muscles, while the mucous membrane is dissected free from the upper wound edge for about 1 cm (⅜ inch) In this way the external maxillary artery is encountered and ligated Posterior and more superficial to the external maxillary artery the facial vein is found and is also ligated and separated Still more posterior and above is Stensen s duct care must be taken not to injure it The mucous membrane is now separated 1 cm (⅜ inch) above the main flap tapering off in its lateral half (Fig. 74 *a*) This tiny mucous membrane flap is now turned outward to form the right half of the vermilion border (Fig. 74 *b*) The lateral third of this new lip owing to thickness of the subcutaneous and muscle tissue is broader than the median parts, which results in protrusion instead of gradual disappearance of the lateral part of the vermilion border It can be avoided by excising some of the subcutaneous and muscle tissue of the lateral third of the new lip and trimming the mucous membrane accordingly

mucous-membrane and muscle defect in front of the masseter muscle, as well as a secondary skin defect at the origin of the lateral half of the flap To close the muscle and mucous-membrane defect, the author advises the following procedure By retracting the free edge of the masseter and buccinator muscles backward (Fig 74, *b*) the oral mucous membrane is widely mobilized so that it can be pulled forward This may be facilitated by a posterior relaxation incision The muscle defect is closed with a flap of the masseter muscle, consisting of its anterior lower half, which is separated from the underlying buccinator muscle and shifted anteriorly into the muscle defect (Fig 74, *c*) , or by only making a vertical relaxation incision through the middle of the masseter muscle and shifting the anterior half of the muscle forward The closure of all defects is now carried out in the following order connection of the lateral edge of the new vermilion border to form the commissure of the mouth, connection of the mucous membrane of the flap with the gums, closure of the posterior mucous-membrane defect as far as possible by mobilization of the posterior mucous membrane, connection of both flaps to each other in a three-layer suture, connection of the masseter flap to fill the defect; connection of the lateral half of the main flap with the skin edges, and closure of the secondary skin defect by starting with closure of the lateral corner. This is easily accomplished since the outer angle has been made smaller than a right angle (Szymanowski) (Fig 74, *d*) A drain is inserted in the lateral lower wound angles Some adjustment may be necessary below the chin to avoid pointing of the same (Fig 74, *d*)

After-treatment The patient is fed by a Jutte tube inserted through the nose Blood transfusions and antibiotics are necessary After three days, he is fed by mouth, his diet being liquid and high caloric The buccal wounds are cleansed with boric acid solution after each feeding Drains are removed after two days, the sutures after five days

Variations and Combinations The same operation can be performed unilaterally for unilateral lesions In extensive unilateral tumors, particularly those extending into the cheek, a unilateral Dieffenbach operation can be performed on the affected side and a Burow operation on the other side (Case 27, p 884) If in the unilateral lesion the tumor has grown around the commissure into the upper lip, a unilateral Dieffenbach operation is performed, with excision of a Burow triangle at the upper lip (Case 26, p 882) If the tumor involves the entire lower lip and part of the upper lip, a bilateral Dieffenbach operation is performed, with excision of a sufficiently wide triangle of the affected part of the upper lip (Case 29, p 886)

outer edge of the newly formed vermilion border This incision penetrates the mucous membrane and the muscles The entire flap is now turned downward and by blunt dissection separated from the mandible until the submandibular spaces are exposed—an important step, since the flap will not be flexible enough unless it is separated entirely from

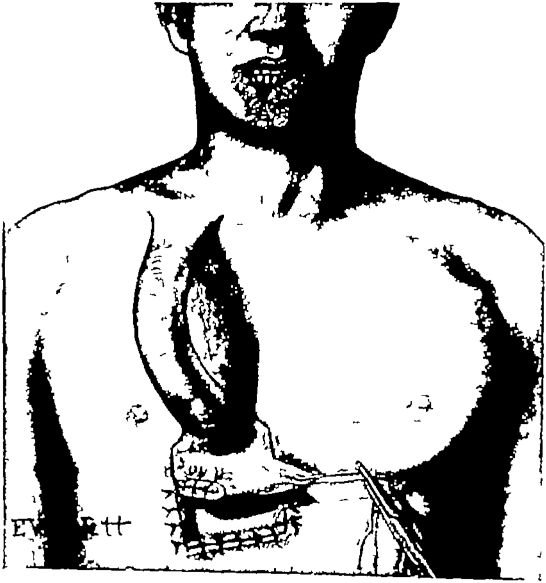


Fig 75, b Two or three months later flap is lined by folding peripheral end over Note that untubed part is raised with exception of bilateral small bridge near transition of untubed part into tubed part, to hold flap in place. Raw surface of flap bed is skin-grafted.

the mandible Great care should be taken not to injure the arteria maxillaris externa The right flap is formed and mobilized similarly

CLOSURE OF DEFECTS Both flaps which have surprising mobility are shifted toward the midline into the defect. This creates a secondary

flap method is applicable (for lining of flaps, see p 202, compare also with Case 14, p 864) If the latter is used, the distal pedicle is left untubed, the length of this part should be carefully planned and measured If it is to provide the lining by folding the distal end over, the untubed part has to be made longer than it would be if skin-grafting were to provide the lining The different steps necessary for transplantation of a lined tube flap to cover lower lip and chin are outlined in Fig 75 The vermilion border is replaced from the opposing lip (Figs 63, 64)

DEFECTS OF LOWER LIP, CHIN, AND MANDIBLE

These large defects, consisting of the soft tissues and parts or the entire horseshoe-shaped section of the mandible, are due to injury or disease (extensive carcinomas). If a sufficient amount of soft tissues surround the defect to permit formation of local flaps, the mandible is splinted temporarily with an intramedullary wire (see p 426), the soft-tissue defect is closed primarily, while the defect in the bone is bridged with a bone graft in a second stage

Transplantation of Local Flaps *Excision of Lower Lip, Chin, and Middle Section of Mandible for Carcinoma of Buccal Side of Lip, Invading Mandible* The following steps are required (1) formation of two Dieffenbach flaps (p 208), (2) resection of the mandible after it has been freed from the soft tissues of the floor of the mouth, (3) temporary splinting of the mandible with an intramedullary wire (p 426), (4) suturing the wound edges of the floor of the mouth and the base of the tongue to the mucous-membrane lining of the flaps, which have been rotated into the defect, (5) replacement of the bone defect, by bone transplantation three months later (p 423), unless there has been infection (in which case one ought to wait three months before transplanting bone and one should administer penicillin preoperatively and postoperatively)

Instead of the Dieffenbach flaps, other local flaps may be applicable, so, for instance, for defects comprising more of the chin-mandible region than the lip, Dieffenbach's principle in the opposite way may be possible, that is, the base of the flaps at the cheeks instead of at the mandible If more of the lip than of the chin is lost, the chin part may be moved upward after a horizontal relaxation incision at the neck and wide undermining and mobilization of skin and subcutaneous tissue The defect at the side of the relaxation incision is skin-grafted

Reconstruction in Extensive Injuries. *Extensive Loss of Soft Tissues and Bone in War Injuries* If the soft-tissue defect cannot be closed by

Additional Procedures If the mandible is involved it can be resected at the same sitting and splinted temporarily with an intramedullary wire (see p 426) Dissection of the cervical lymph glands if indicated however should be carried out in the second stage since this procedure necessitates resection of the external maxillary vessels This would consequently endanger the circulation of the cheek flap if carried out primarily

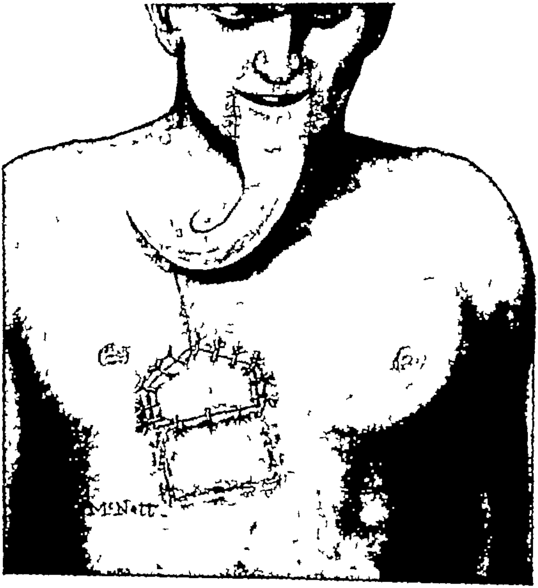


Fig. 75 c Flap is sutured into defect.

Transplantation of Distant Flaps. *Use of Lined Flap* In very large defects in which flaps from the neighborhood are not applicable a flap from distant parts must be used. If possible the acromiopectoral or chest region should be the donor site. The lined open-flap method or the tube

the triangle. Now the triangular flap is formed from the sound lip opposite the defect (for technic, see p 192), and rotated into the defect. Then follows the closure of the secondary defect. In a second stage, the pedicle of the flap is severed and adjusted as outlined in Fig 66.

If the defect includes the entire commissure of the mouth, together with larger parts of the cheek, the Dieffenbach or Burow method for closure of the defect may be applicable (see p 208, Cases 22, 26, 29, pp 876, 882, 886).

CLEFTS OF LIP AND PALATE

Congenital clefts of face and palate are caused by lack of fusion of the various processes that form the face and its bony structures. Undoubtedly, some of these malformations are inherited, as Fogh-Andersen deduces from an excellent genetic study of his large Danish material, but for the majority, particularly the isolated cleft-palate cases, the cause is unknown. Clefts of the lip and palate are the most important and most frequent ones. Clefts of the nose and oblique and transverse clefts of the face are rare. Their structural appearance is not so regular as that in clefts of the lip and palate. Hence, the surgical procedures differ and have to be adapted to each case.

Classification of Clefts

From the embryonic viewpoint, the cleft of lip, alveolar process, and palate must be considered as one unit, from the surgical viewpoint, however, a subdivision is more feasible, since the operative requirements differ with each cleft. Ritchie, impressed by the observation that the condition of the alveolar process has the most important influence in determining the requirements for surgical repair, grouped the cases according to the presence or absence of a cleft in the alveolar process. This, indeed, provides an excellent approach.

Group 1. Prealveolar-Process Cleft: In this group, the cleft is in front of a normal process. Rarely is it associated with a cleft of the palate. The cleft is incomplete or complete, depending on whether the lip alone is involved or the cleft reaches into the nose. The defect may be unilateral or bilateral. It is rarely median.

Group 2. Postalveolar Cleft: In this group, the cleft is in the palate behind a normal process. Rarely is it associated with a cleft of the lip. The palatine cleft may involve only parts of the palate or the entire soft and hard palate, reaching from the uvula to the anterior palatine foramens.

The cleft may be unilateral or bilateral, terms which are not quite correct but are descriptive. In the unilateral cleft, the lower border of the vomer is attached to one of the palatine processes, so that the oral

the use of local flaps, as after extensive war or other injuries the necessary reconstructive steps are as follows (Ivy)

1 Arrest of hemorrhage counteracting loss of control of tongue and thus danger to respiration by pulling the tongue forward (either with a suture or large safety pin anchored to the dressing) débridement of the wound and wound excision if necessary fixation of bone fragments in approximately normal position by wires or other (extraoral) appliances adjustment of torn tissue flaps dependent drainage antibiotics

2 Final reduction and fixation of the fragments of the mandible by special splints (such as made of acrylic resin affording a clear view of the underlying teeth and gum tissues and providing feeding space)

3 After all wounds look clean and healthy a lined flap is transplanted to cover the soft-tissue defect.

4 Three months later the bone defect is replaced by bone transplantation unless there has been infection in which case one ought to wait three months before transplanting bone (and to provide preoperative and postoperative administration of antibiotics)

5 Provision of artificial dentures to replace lost teeth

As far as choice of flaps is concerned the open acromiopectoral flap is best suited (for construction of open flaps see p 72) Local flaps if available are utilized to replace the missing lining These flaps may be taken from the cervical region with the base at the tongue and hinged upward. Smith's principle to improve the circulation at the base of the flap may be advisable (p 196) If local flaps for lining are not available the pectoral flap is constructed so that the peripheral pedicle is folded over This principle and the way of transfer are similar to those described on p 213 (Case 14 p 864) Schuchardt and more recently Kazanjian and Converse have described many useful flap transplantations in their well illustrated monographs.

DEFECTS OF COMMISSURE OF MOUTH AND PARTS OF ADJACENT CHEEK

If the defect includes only one half of the commissure of the mouth (the corner part of either the upper or the lower lip) and parts of the adjacent cheek and if the defect can be made triangular Estlander's method is the operation of choice Case 21 p 874 is a typical example. Before rotating the vermilion bordered triangular flap into the defect the defect is made smaller by starting with closure of the lateral corner of

lip upon the alveolar process tends to favor approximation of the severed bony arches The author prefers to repair the cleft lip between the fourth and sixth weeks if the child is gaining weight and is healthy

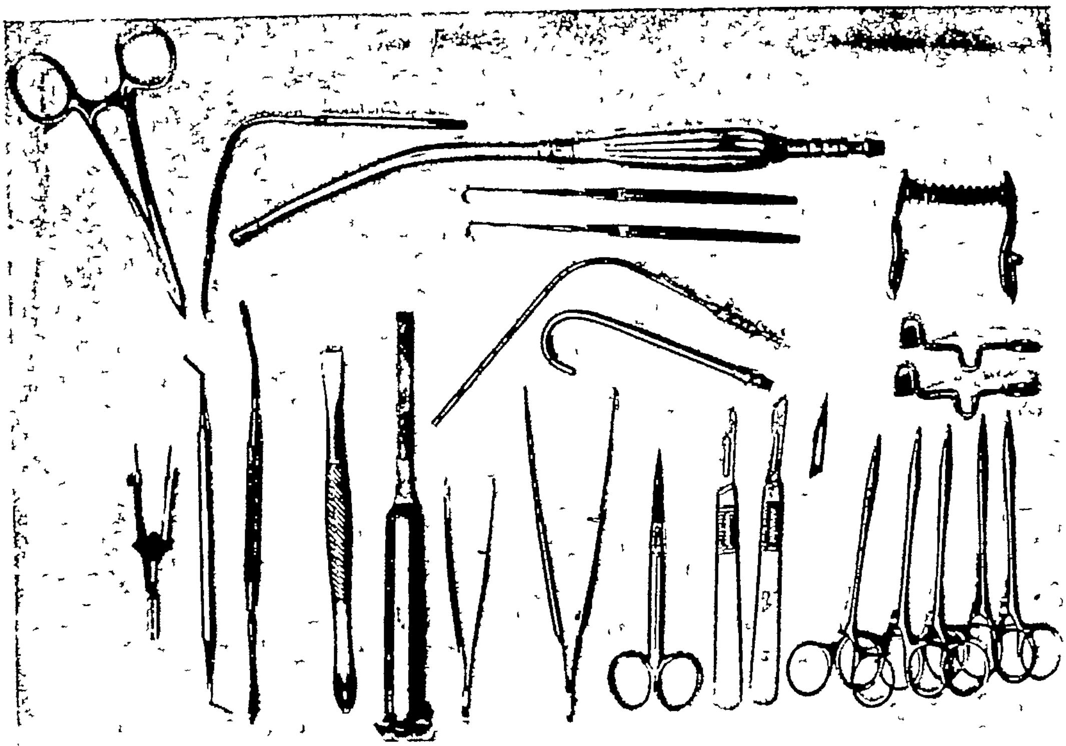


Fig 76 Instrument table, set for surgery in cleft lip and cleft palate

As to when the *cleft in the palate* should be closed, controversies have arisen recently As a result of the extensive and interesting research of Slaughter and Brodie on facial growth, they advise a delay of closure of clefts in the palate until the child is about five years old According to their findings, the face develops rapidly until about the fifth year The middle portion of the face develops from the growth centers of the maxilla (frontonasal, zygomaticomaxillary, pterygomaxillary sutures), any disturbance of these growth centers, as may be caused in cleft-palate operations by an impairment of blood supply to the maxilla, might result in failure of the middle portion of the face to move forward at the same rate as the rest of the face Kazanjian had previously called attention to the development of the maxilla in operated and nonoperated cleft-palate cases In the nonoperated cases, the separate halves of the palate developed and achieved a harmonious relation to the mandible, even though the cleft in the palate remained Hence, a reasonable operative delay may result in more normal growth, on the other hand, however, it may cause a permanent speech impediment, since functional development will

cavity communicates with only the left or the right nasal cavity In the bilateral cleft there is no connection between the vomer and the palatine processes, hence the oral cavity communicates with either nasal cavity the vomer hangs free in the middle

Group 5 Alveolar Process Cleft In this group the alveolar process is unilaterally or bilaterally cleft and as a rule associated with a cleft of the lip or palate or much more often with both. Such a through and through cleft, if unilateral, passes through lip, floor of one nostril alveolar process between the vomer on one side—which is attached to the opposite processus palatinus—and the processus maxillaris on the other side and the soft palate. This combination of all clefts is the most frequent one In bilateral through and through clefts the cleft passes on each side of the premaxilla through the lip through the floor of the nostrils, through the hard palate on each side of the vomer and through the soft palate The vomer hangs free in the cavity In front of it is the isolated premaxilla which is displaced forward and often rotated upward occasionally it is displaced laterally Median clefts are rare

The majority of clefts occur on the left side and the through and through cleft is the commonest one

General Considerations

The object of the operation is the closure of the cleft and as far as possible the providing of normal anatomical conditions In a through and through cleft closure of the entire cleft in one sitting would be too extensive Hence the repair work must be divided into two or more stages The cleft of the lip and the alveolar process is closed first since it is not only the most visible part of the defect but also as far as feeding and development of the severed alveolar process is concerned the most disturbing factor The cleft of the palate impedes feeding but not to such a degree as to cause nutritional disorders Hence its closure is delayed until it causes a definite handicap to the child that is when the child learns to speak

Time of Operation As to when the *cleft of the lip* should be closed has been a matter of dispute for a long time The present consensus is that the baby should be given at least two weeks time to become adjusted both to his feeding and in general Accordingly, the earliest time to operate is the fourteenth day In cases where the cleft of the lip is associated with an alveolar process cleft, it is inadvisable to wait longer than three months The cleft tends to become wider with each consecutive month and closure becomes more and more difficult. Within the first month the bones are pliable hence the normal pressure of the closed

an infant cannot tolerate lack of oxygen and lack of fluids The instrumentarium is simple Some of the special instruments used for cleft lip, as well as cleft palate, are depicted in Fig 76

Cleft Lip

Cleft lip, ordinarily called "harelip," is a prealveolar cleft if confined to lip or to lip and nostril, consequently, this type of cleft lip belongs to Group 1 of the foregoing classification In the majority of cases, however, cleft lip is associated with an alveolar and postalveolar cleft, and belongs to Group 2 of the classification Innumerable procedures are proposed for closure of the defect An excellent collective review of the history and technical development of cleft-lip repair has been made by A D Davis The older methods aimed at the closure in *primitive* fashion, without regard to the cosmetic result The vermilion border, lining the cleft edges, was sacrificed and the cleft closed by simply uniting the wound edges Mıault was the first to utılıze the vermilion-border lining, thus impıoving the appeaıance of the lip His method became, more or less, the basic principle for modern procedures

One objection is the straight-line scar, which produces a straight, flat lip in the profile view and may, if contracting, cause a notch in the vermilion border. A normal lip, as seen in profile, bulges forward at and just above the vermilion border. To reproduce this "break," or pout, in cleft-lip repair (it occurs about two thirds or three fourths of the way down the lip), Blair and Brown modified the Mirault operation in such a way that an extra amount of tissue was provided at and above the vermilion border, but the standard flap that was described then was half the length of the lip and too large in some patients Brown and McDowell overcame this by using a small triangular flap to produce the fullness in only the lower one third or one fourth of the lip (Figs 77 to 84) This principle became widely accepted until it was challenged recently by LeMesurier, who modified the old Hagedorn quadrangular-flap method He was soon followed by Steffensen, Bauer, Trusler and Glanz, Brauer, Gelbke, and others In this operation, a quadrangular flap is used from the side of the cleft and swung down and over to the median side of it to fit into a notch created in the philtrum Some of those who now use the quadrangular-flap method after LeMesurier formerly used the triangular-flap method of Mirault, Blair, Brown, and McDowell According to their experience, the quadrangular method produces consistently better results than any other, that is, it provides adequate fullness of the lower third of the lip, notch formations are counteracted by the change in the direction of the scar to a "stepline" (Fig 97).

not occur in an unoperated soft palate cleft unless it is subjected to normal use Not all cleft palate operations with early closure result in interference with maxillary growth particularly those for closure of partial clefts, and the interference with growth seems to be directly proportional to the amount of injury to the growth centers and to diminution of blood supply to the parts concerned Thus if the delicate tissues are handled with the utmost care it may be better to operate than to delay the closure beyond the time the child learns to speak i e beyond the second to the third year Instead of extensive mobilization of oral mucous-membrane flaps greater use should be made whenever possible of the mucoperiosteal vomer flap (Waldron Dunn)

The author has seldom seen postoperative retrusion of the maxilla and is supported in this by Trusler and others but it does occur Some of these deformities result not from disturbance of the maxillary growth centers but from tightness of the upper lip after lip repair Rosenthal called attention to this and thought to prevent it by closing the lip after eruption of the first upper incisors i e within the ninth month of life. Late closure, however has many disadvantages as pointed out above and is seldom necessary since undue pull can be avoided by thorough mobilization and relaxation of the cheeks and creation of *fullness of* the lip

Preoperative Preparation The preoperative preparation should start with an evaluation of the general condition of the child. No operation should be planned unless the child is gaining weight and is in good general health Close cooperation with the attending pediatrician is absolutely necessary He informs the surgeon whether the child is ready for the operation or not If ready the child is admitted to the hospital forty eight hours before the operation A careful physical examination is made which includes urinalysis Wassermann blood test, a complete blood count, and the bleeding and clotting time The latter two should be normal and the hemoglobin above 70 per cent. Feeding is given up to six hours, water up to two hours before operation Atropine—dosage to be determined by the pediatrician—is given one hour before the operation A blood donor should be on hand

The child is anesthetized with ether which is administered by the drop method until the second stage of anesthesia is reached The face is now washed with soap and water and the operating field draped Ether vapor is administered intranasally through a catheter or through an endotracheal tube Either one should be attached to a Y tube so that oxygen can be bubbled through the ether with *minimal* pressure An intravenous or rectal drip should be employed for there are two things that

Brown and McDowell defend their triangular-flap operation, their method requires no discarding of skin This is an important point In the quadrangular-flap method, some skin must be discarded, in rather wide cleft lips, the author has encountered much difficulty in closing the upper part of the cleft Another disadvantage is the rather complicated geometrical design, which is typical of both methods In addition, after the initial incisions have been made, final corrections, if necessary, are barely possible

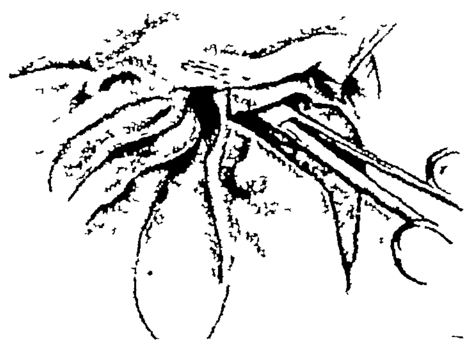


Fig 80 Undermining between the lining and skin of the nostril so that they will slide on each other when the nostril is rolled up into a tube At times it is necessary to make the little vertical cut shown just in front of the turbinate to allow complete rotation of the nostril (J B Brown and F McDowell Surg, Gynec. & Obst)

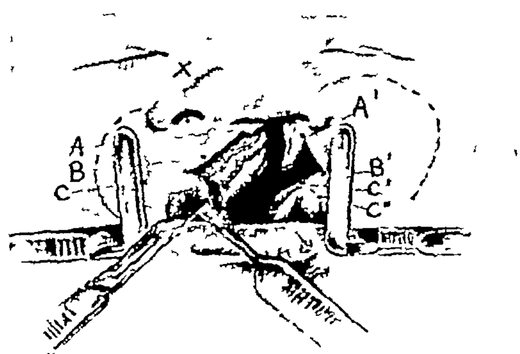


Fig 81 The lightly incised lines *a-b-c* and *a'-b'-c'* are cut completely through the lip with a stab blade, with care to keep knife exactly perpendicular to lip All angles should be completely opened The vermilion is inspected and any attached skin removed with a stab blade The rectangular flap freed from *a'-b'-c'* must be loose enough to be rotated up 180 degrees into nostril floor Dotted lines indicate area undermined. (J B Brown and F McDowell Surg, Gynec & Obst)

For many years, the author has followed Axhausen's technic of cleft-lip repair Since the revival of the quadrangular-flap method, he has applied this principle to the Axhausen technic with exceedingly gratifying results A fullness of the lower one fourth of the lip is achieved without sacrificing much skin, the designs are simple, and final determination of length and adjustment of the quadrangular flap are made at the end of the operation so that changes can still be made This is an important and simplifying feature

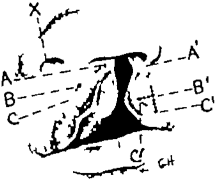


Fig. 77: The triangular flap operation for cleft lip repair The V-excision is marked out first. *c* is on the mucocutaneous junct.on at the most medial point of good full vermilion. *b* is on the line *a-c* equidistant from *c* and *c* The incision is *a-b-c* saving the mount of lip indicated by the shaded isosceles triangle in the insert drawing *b* is on the mucocutaneous junction, the same distance from *c* that *b* is from *c* (J B Brown and F McDowell Surg., Gynec. & Obst.)

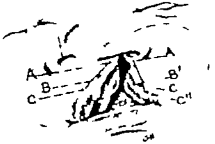


Fig. 78 The lines *a-b-c* and *a-b-c* are lightly incised with a knife The incision is carried upward from *c* on the mucocutaneous junction to separate the vermilion from the skin. This is also done at *a* to keep any vermilion out of the nostril floor The circular dotted lines show the area which is to be undermined at the next step. (J B. Brown and F McDowell Surg., Gynec. & Obst.)

Fig. 79 Incisions are made in the buccal fornix on both sides and the soft tissues of the lip and cheek are taken loose from the bone up almost to the lower border of the orbit on the cleft side Less extensive mobilization may be necessary on the sound side though it is sometimes necessary to elevate that nostril out of the pyriform recess and to cut the base of the septum slightly before the normal ala and columella can be straightened. In any event, the mobilization is continued until the nose can be straightened and the two sides of the lip can be brought together without tension. (J B. Brown and F McDowell Surg Gynec. & Obst.)

later, that is, any time after Stage 2—one may wait until Stage 5 Should the markings prove later on to be not quite accurate, adjustment is still possible in Stage 5 The markings are made with percutaneous dots by the tip of a hypodermic needle dipped into methylene blue

Point *a* is marked out first It is located on a level with the base of the columella at the very tip of the median vermilion-border lining (mucocutaneous junction) of the lip cleft Point *a′* is located at the tip

Fig 85 Outline of square notch on the philtrum side of cleft and quadrangular flap on lateral side to fit into notch (compare with Figs 86 and 95)

of the lateral vermilion border where it joins the tip of the laterally displaced ala Points *b* and *b′* are found as follows The median part of the upper lip is pulled by a finger into correct position, in this way, the cupid bow (juncture of philtrum and mucocutaneous border of the vermilion) becomes visible, at least its point opposite the cleft If the corresponding point at the cleft is not visible, it is imagined near the vermilion border at the same level as the other point This is Point *b* Point *b′* is marked out on the lateral cleft side, and is the same distance from *a′* as *b* is from *a* *C* is marked out 2 or 3 mm above *b* To find *c′*, a perpendicular is erected on *b* for 2 or 3 mm (equal distance of *b* to *c*); this is Point *x*; 2 or 3 mm from *x* toward *a′* is *c′* Point *c′* is marked out and connected by a slightly laterally curved line with *a′* Adjustment of these markings for formation of the lateral vermilion-border flap can still be made at the end of the operation (compare with Fig 95)

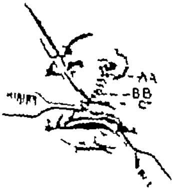
Formation of Floor of Nostril (Figs 87 to 89). Only the anterior of the floor is reconstructed, that is, no farther back than just behind the alveolar process It is constructed by using turnover flaps taken from

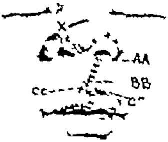
TOTAL UNILATERAL CLEFT

The technic of Axhausen will be described in detail for this most common deformity the through-and through cleft (Group 3 p 217 Fig 85 Cases 12–14 pp 891–893)

Technic (Axhausen LeMesurier) The preoperative preparation has been described The repair is divided into the following stages

1 Outlining of the lip incisions
2 Formation of the floor of the nostril
3 Correction of the alar displacement
4 Correction of the septal displacement
5 Closure of the lip





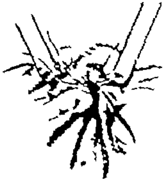


Fig. 82 *a* and *a'* are approximated with a deep stitch of white silk or cotton or No. 000 catgut (knot on the mucosal side) and a surface suture of No. 000 black silk. *b* and *b'* are approximated with a fine deep white stitch and a black one on the surface. Intervening fine surface sutures are placed and an oblique cut is made in the vermilion flap from *c'*. For the incisions and trimming fine very sharp scissors are most useful. (J. B. Brown and F. McDowell: Surg. Gynec. & Obst.)

Fig. 83 *c* and *c'* are united and the vermilion flaps are interdigitated in a zigzag fashion, fitting them so that they lie naturally together without any pull or stretching. Suturing is then continued on around the vermilion border and up the inside to the fornix. The little flap in the nostril is trimmed to fit with the one from the opposite side and they are sutured together to form the floor. A few key mattress sutures are placed through the ala to unite the lining and covering (which were separated during the undermining). (J. B. Brown and F. McDowell: Surg., Gynec. & Obst.)

Fig. 84 The mucosal suturing is important and is done with fine interrupted stitches and careful trimming to fit the edges together. The upper corners are rounded somewhat, and the suturing is continued to pull some mucosa into the lip from either cheek. This advances the whole lip and thrusts it forward. If the superior edge of the mucosa is tight, vertical slits are made on either side and allowed to spread open. (J. B. Brown and F. McDowell: Surg., Gynec. & Obst.)

Outlining of Lip Incisions (Figs 85 86) Although it is possible without previous designs to create a square notch on the philtrum side and a quadrangular flap on the lateral side to fit into this notch (Figs 85 & 91) it is more accurate to plan the incisions as shown in Fig 86 The design is made immediately The actual incisions however are made

Fig 90 The alar flap is sutured posteriorly to the turnover flaps and with its tip to the tuberculum of the columella which is near point *a* of Fig 86 (H May Plast & Reconstruct Surg)

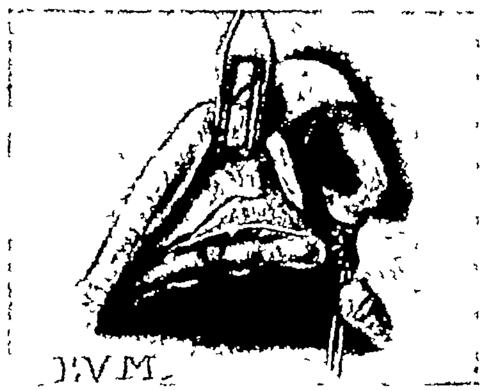


Fig 91 Correction of the septal displacement An incision is made along the sulcus, care being taken to leave a rim of the mucosa attached to the gums to facilitate later suturing The soft tissues are mobilized from the bone until the cartilaginous septum and the floor of the nose is reached (H May Plast & Reconstruct Surg)

Fig 92 The mobilized mucosa is now advanced laterally by pulling it with a forceps in that direction and fastening it in this position with catgut sutures (H May Plast & Reconstruct Surg)

the median and lateral walls of the cleft Thus, the cleft of the alveolar process is closed but the cleft behind remains open until the palate is repaired

The first step is the formation of a median turnover flap (Fig 87) With a retractor the nostril is shifted forward and an incision is made just behind the rim of the columella from its tip to the ridge of the

Fig. 86 Outline of lip incisions (Axhausen-Hagedorn-LeMesurier Technic of Cleft Lip Repair): Point *a* is marked out first. It is located in level of the base of the columella at the very tip of the median vermilion border line of the lip cleft. Point *a'* is located at the tip of the lateral vermilion border where the latter joins the tip of the laterally displaced ala. Points *b* and *b'* are found as follows: The median part of the upper lip is pulled with a finger into correct position in this way the cupid bow becomes visible, at least its point opposite to the cleft. If the corresponding point at the cleft is not visible it is imagined at the vermilion border in the same level as the other point—this is point *b* Point *b'* is marked on the lateral cleft side and is of equal distance from *a'* as is *b* from *a* *c* is marked out from *b* for about two to three millimeters above *b* To find *c'* a perpendicular is erected on *b'* for about two to three millimeters (equal distance of *b* to *c*) This is point *x*. Two to three millimeters from *x* towards *a'* is *c'* (H May: Plast. & Reconstruct. Surg.)

alveolar process The knife is now turned horizontally and the incision curved around the alveolar process ending posteriorly where premaxilla and vomer meet The mobilization of the flap is difficult it should be carried out under sharp dissection avoiding perforation of the flap and injury to the septal cartilages. The flap should not be extended farther posteriorly than to the groove that is formed by the insertion of the vomer to the premaxilla otherwise the flap will tear at this point and may need replacement by a small turnover flap from the vomer

The next step is the formation of the lateral turnover flap This step is combined with an incision along the gingivolabial sulcus and mobilization of the soft tissues of the cheek (Figs. 88 89) The incision starts at the edge of the alveolar process and is led to the point where alveolar process tip of ala and vermilion border meet and from there upward

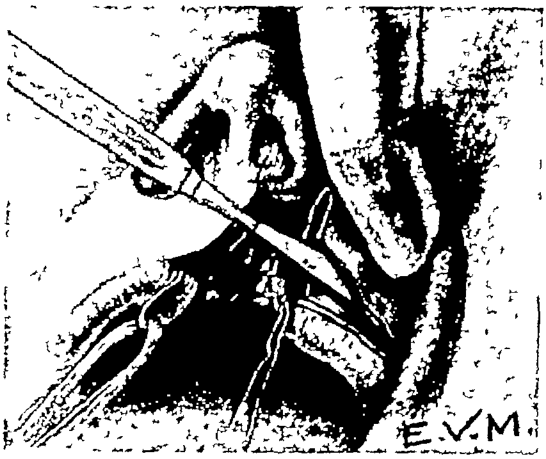


Fig 93 The cheek which has already been mobilized partially from incision along the lateral gingivolabial sulcus—a rim of mucous membrane should be left attached to the gingival side to facilitate later suturing—is now thoroughly detached from the underlying bone with knife and periosteal elevator up to the foramen infraorbitale, i e , until the infraorbital nerve is reached (H May Plast & Reconstruct Surg)

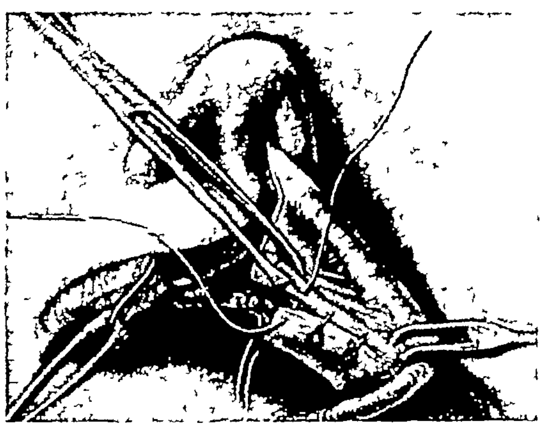


Fig 94 Median advancement of the lip lateral to the cleft by advancement of the mucosa along the lateral gingivolabial sulcus The lateral and median wound edges are united in front of the alveolar process with the stitch which had been left long previously (Fig 89) (H May Plast. & Reconstruct Surg)

Fig 95 Closure of the lip Formation of the square notch on the median side of the vermilion border flap, the lateral side of the vermilion border flap is cut square and is adjusted into the notch on the median side (Compare with Fig 86) (H May Plast & Reconstruct Surg)

89) and proceeds upward and laterally along the base of the ala for about 0 5 to 1 cm ($\frac{3}{16}$ to $\frac{3}{8}$ inch) After the anterior and posterior incisions have been connected, the small alar flap is mobilized and sutured into the upper wound angle of the columella the posterior edge is sutured to the median and lateral turnover flap the anterior edge to the outer wound edge of the columella (Fig 90) Care should be taken to unite the tip of the ala with the tuberculum of the columella which is near Point *a* of Fig 86 Its location can be facilitated by forming part of the vermilion border flap (*a-c* of Fig 86) before adjustment of the ala After application of an elastic clamp to the right side of the upper lip to reduce bleeding, an incision is made from *a* to *c* just within the skin (Figs 86 90) The tip of the vermilion border is now grasped and a whole thickness vermilion border flap cut down to Point *c* but no farther The alar flap can now be accurately adjusted as previously described (Fig 90)

Correction of Septal Displacement (Figs 91 92) The extramedian displacement of the septum is corrected by advancement of the mucous membrane along the median gingivolabial sulcus An incision is made along the sulcus care being taken to leave a rim of mucosa attached to the gums to facilitate later suturing The soft tissues are mobilized from the bone until the cartilaginous septum and the floor of the nose are reached The mobilized mucosa is now advanced laterally by pulling it with a forceps in that direction and is fastened in this position with catgut sutures

Formation of Lip (Figs 94 95) Prior to the closure of the lip cleft a vermilion border flap must be made from each side of the cleft. The median one is already partly formed It is now extended along the dotted line of Fig 86—i e across the philtrum and parallel to the vermilion border—and cut off along the vertical dotted line of Fig 86 The lateral vermilion border flap is now cut along the line *a'-c'* however it is better to stop the incision before reaching *c'* and to estimate the proper length of the flap at the end of the operation Before the lip is sutured the mucosa along the lateral gingivolabial sulcus is advanced The cheek which for this purpose has already been partly mobilized (Fig 88) from an incision along the lateral gingivolabial sulcus—a rim of mucous membrane should be left attached to the gingival side to facilitate later suturing—is now thoroughly detached from the underlying bone with knife and periosteal elevator up to the foramen infraorbitale i.e., until the infraorbital nerve is reached (Fig 93) and advanced mediad along the lateral gingivolabial sulcus (Fig 94)

SUTURING The lateral and median wound edges are united in front of the alveolar process cleft (Fig 94) The last suture to be inserted is

to correct the inequality by merely lengthening the lateral vermilion-border flap The next step is fitting the lateral vermilion border into the notch of the median side by proper shortening (For final results, see Figs 96, 97, Cases 32–34, pp 891–893)

At the end of the operation, the nostril of the cleft side may not match the other side No attempt should be made to correct the deformity at this stage unless it needs a minor correction such as increase of the columella-alar angle by removal of a crescent of skin and cartilage from the angle (Fig 96) . Major deformities should be eliminated when the child is about five years of age for the following reasons The pull of the soft tissue after closure of the cleft will in time cause the displaced underlying bony framework to change position, and this in turn will cause a shift of the soft tissues Any correction of residual deformities around the nose before the anatomy has settled is a waste of time, although others, notably Gelbke, disagree with this statement (see also p 245) Further, should the immediate correction not have been successful, the cartilages may be so damaged from the primary correction that secondary repair is fruitless.

After-Treatment: The lip wound is painted with collodion A Logan bow is strapped to the cheeks to relieve tension on the suture lines and to protect the lip As soon as the child is awake, it is fed with a small spoon or a dropper The elbow joints are immobilized with cardboard cylinders or splints so that the child cannot touch the wound The skin wound remains exposed The skin sutures are removed on the fifth postoperative day The baby can usually be fed with a bottle after the tenth postoperative day, but the holes in the nipple should be enlarged

INCOMPLETE CLEFT LIP

A technic similar to that described in the foregoing paragraphs is applicable whether the cleft reaches the floor of the nostril or not In the latter case, the triangular-shaped indented skin above the cleft is excised The tip of the triangle becomes Point *a-a′* of Fig 86, from which the remaining marking-points are selected The technic from then on is practically the same as already described, except that the floor of the nostril is already formed There is always, however, asymmetry at the nasal entrance, which requires advancement of the vestibular mucosa on the median as well as on the lateral side

For results, see Case 31, p 890 For after-treatment, see above

TOTAL BILATERAL CLEFT

In total bilateral clefts, the prominence of the premaxilla increases the width of the cleft (Fig 98) , and hence makes closure more difficult

taken from the nostril suture which has been left long (Figs 89 94) One end of this suture is passed through the lateral the other end through the median mucosal edge After the suture is tied, the remaining gap in the alveolar process is closed.

The lip is now formed, and is sutured in three layers First, the oral mucous membrane is sutured with 00000 chromic catgut this is followed

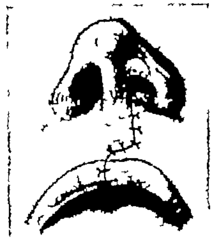


Fig. 96 The wound is sutured in layers. If the nostril is flat a crescent piece of cartilage may be removed at this stage from the columella-alar angle followed by trimming and closure of the skin. (H. May: Plast. & Reconstruct. Surg.)

Fig. 97 a-c) Patient before and after the Axhausen-Hagedorn LeMesurier cleft lip operation. Note normal forward bulge of vermilion.

by suturing of the muscle layer with the same material The stitches are laid in such a way that they can be tied posteriorly Now the skin edges are mobilized from the muscles for a short distance to prevent inversion and sutured together with fine nylon The lowest suture unites Point c and Point c′ of Fig 95 If it is now evident that their two wound edges are of unequal length (the lateral one being the shorter if in the beginning the incision was not completely extended to Point c′) it is possible

advantage After removal of the premaxilla, a prosthesis to replace the missing teeth and to maintain the stretch of the upper lip is made and attached to the upper teeth (Case 35, p 894) The author prefers a temporary "dog-mouth" appearance in these children than a permanent "dish-face" deformity, which may develop as a result of damage to the growth centers of the surgically recessed premaxilla The author agrees with Gelbke and others that, in spite of the growing popularity of surgical recession of the premaxilla, only time will be the judge of the proclaimed merits of this procedure Hence, the author attempts a surgical backward displacement of the premaxilla only when it is absolutely necessary

If the premaxilla is set back, it is set back the least possible amount necessary to close the lip over it or to take its place between the lateral alveolar processes This is done submucously by excision of a block of vomerine bone Removal of a block rather than of a wedge permits the pushing of the premaxilla directly back, like closing a drawer, rather than tilting it back (J B Brown, et al) This operation is performed when the child is four weeks old

Technic: The mucosa is split longitudinally over the vomer and reflected from it The amount of protrusion is measured and a vomer block of 3 to 4 mm less than this amount is removed with a small chisel from directly behind the premaxilla The premaxilla is then pushed back Any deviation or rotation of the premaxilla should be corrected at the same time A thin Kirschner wire is drilled through the premaxilla in the lower prolabial area backward into the vomer (Cronin) The protruding end of the wire is cut off short so that the prolabial tissues can be pulled over it About six weeks later the Kirschner wire is removed through a small stab incision over the easily palpable wire The bilateral lip cleft is repaired at this stage Closure of the lip cleft at the time of the recession of the premaxilla can be performed only when the premaxilla is slightly larger than the space between the two lateral processes, firm immobilization can be obtained by tight fitting and Kirschner wire immobilization If recessing the premaxilla and closure of the lip clefts is done in one stage, care must be taken (1) not to detach the prelabium from the premaxilla—otherwise, an aseptic necrosis of the latter may occur, (2) to recheck the position of the premaxilla at the end of the operation and to make sure it is really up and back in the right place

In closing the lip cleft, thorough mobilization of the soft tissues is sufficient to permit an easy closure The soft tissues of the entire premaxilla, including the vermilion border, are saved, even if the philtrum

The premaxilla is the anterior part of the embryonic frontonasal process which as a rule fuses with the lateral maxillary (alveolar) processes to form the upper dental arch In complete bilateral lip clefts the three processes are separated from each other The premaxilla with the pre labium sits in front of the vomer and usually protrudes considerably forward with or without lateral or upward tilt. Its shape varies All these factors have considerable bearing upon the proper surgical man agement of the premaxilla. As a rule a surgical backward displacement

Fig. 98 G Axhausen Technik und Ergebnisse der Lippenplastik. G Thieme, Leipzig.

of the premaxilla should be attempted only if it is absolutely necessary (1) in extreme forward displacement of the premaxilla to such a degree as to make closure of the lip clefts impossible (2) if the premaxilla is so large that it overlaps the lateral alveolar processes (3) in unfavorable lateral or upward tilt or rotation A surgical backward displacement of the premaxilla after the lip clefts have been closed is indicated when its backward *movement (or forward movement of the alveolar processes)* is so slow that it may arrive too late in the gradually closing cleft of the two lateral alveolar processes to form a bridge between them and instead would take position in front of them Hence it is necessary to follow up these children frequently during the first year to prevent the possibility of this deformity which is known as dog mouth If the deformity occurs it can be corrected only by later removal of the premaxilla (see p 247)

The latter procedure however is not as harmful as it sounds. It can be performed just before the child goes to school and at the same time the shortened columella can be lengthened (see p 245) The anteriorly displaced premaxilla has so far kept the upper lip well stretched—a great

is absent, the lip short, and the vermilion border much smaller than on the lateral side of the clefts In time, a surprising degree of formative adaptation occurs after the operation Both sides are closed in one stage, unless there is much tension on the soft tissues after closure of the first side Then the wider side should be operated on first, the second one four weeks later

Technic (Axhausen) Formation of the floor of the nostril is similar to that described for the unilateral cleft Here again the posterior border of the median turnover flap should not be extended beyond the insertion of the vomer to the premaxilla

Fig 102 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

The various steps for the formation of the floor of the nostril, as well as for the formation of the median vermilion-border flap, are depicted in Figs 99 to 102

The soft tissues of the cheek are now mobilized from an incision along the lateral gingivolabial sulcus, followed by advancement of the mucosa To unite the lateral vestibular mucosa with the mucosa of the premaxilla requires mobilization of the lower mucosal-wound edge of the premaxilla (Fig 103) The lateral mucosal flap is advanced and sutured to the premaxillary mucosa, thus bridging the cleft between alveolar process and premaxilla in front (Figs 104, 105) It is then sutured to the floor of the nostril (Fig 106)

Formation of the median vermilion-border flap is shown in Fig 101, of the lateral one in Fig 103 Closure of the lip and adjustment of the vermilion-border flaps are shown in Fig 107.

The author, however, agrees with J B Brown and others that the vermilion of the prelabium should not be included in the vermilion of the reconstructed lip when the vermilion of the prelabium is thin, this happens in most cases The procedure tends to result in a double notch

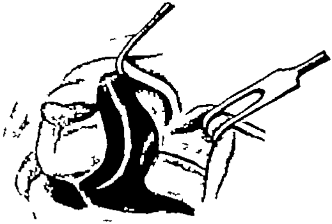


Fig. 99 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

Fig. 100: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

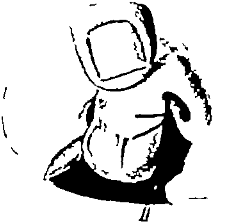


Fig. 101: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

or a scant vermilion-border lining in the center of the lip It is better to make an incision at the mucocutaneous junction all the way around the prelabium and to turn the vermilion of the prelabium backward as a hinge flap, to use it as part of the oral lining of the lip and backing of the center part of the vermilion, as depicted in Figs 108 to 110 (Cases 35–36, pp 894–896)

The second side may be closed in the same operation. If there is too much tension resulting from closure of the first side, however, repair of the second side is postponed for four weeks

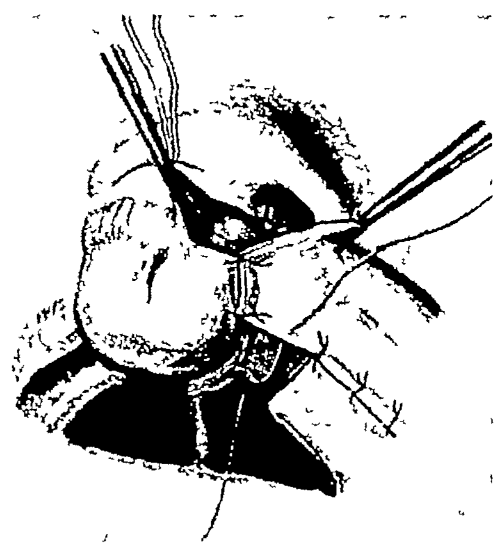


Fig 106 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

Fig 107 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

SECONDARY DEFORMITIES FOLLOWING REPAIR OF CLEFT LIP

These deformities follow dehiscence or faulty primary correction or are perhaps a combination of both In unilateral cases, the most frequent type exhibits four characteristic deformities which are always pres-

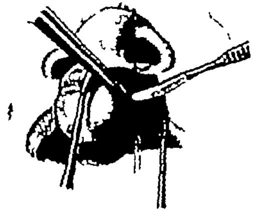


Fig. 103 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

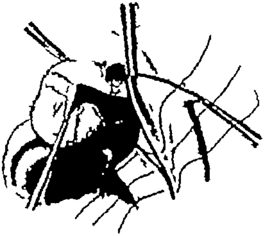


Fig. 104: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

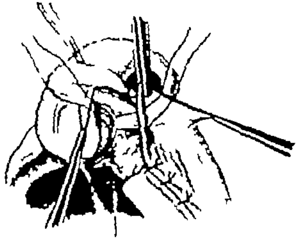


Fig. 105: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

ent, although varying in degree (1) downward-displaced nostril, (2) laterally displaced ala, (3) extramedian position of the septum, and (4) a connection between nasal cavity and vestibulum oris (Figs 111, 112, 118, 119) This frequent type occurs following closure of the lip only, without formation of a nasal floor and without closure of the vestibular cleft Satisfactory correction is possible only after undoing the former repair and secondary reconstruction

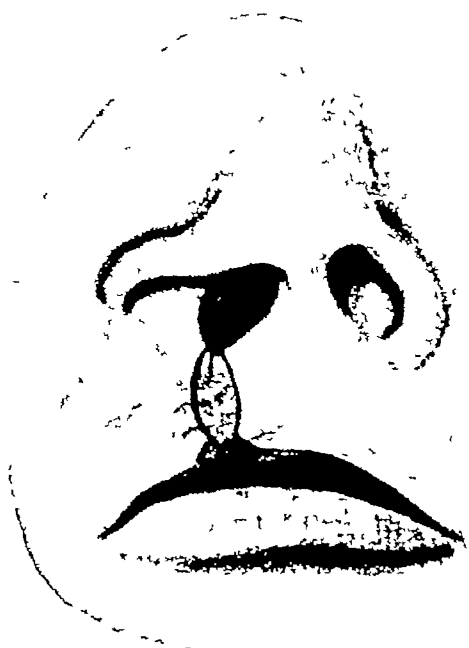


Fig 111 G Axhausen. Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

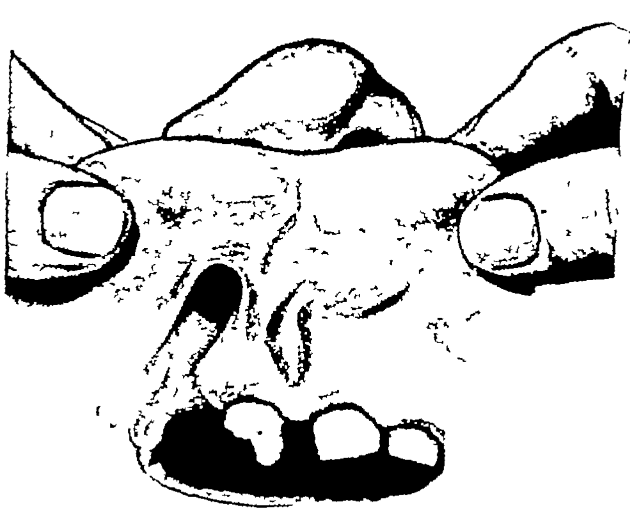


Fig 112 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

Fig. 108: Closure of bilateral cleft lip—after J. B. Brown and F. McDowell. The narrow vermillion of prelabium is not used for reconstruction of vermillion of prelabium per se but turned backward to be used as a hinge flap for oral lining and backing the center part of the vermillion. Corresponding points of junction between lip and prelabium are marked out. A is marked out on mucocutaneous border of prelabium in level of base of columella. A' is located at tip of lateral vermillion border where it joins the laterally displaced ala. B is marked out on lower mucocutaneous border of prelabium perpendicular to lateral border of base of columella. B' is of equal distance from A' as A from B

Fig. 109: From an incision at the mucocutaneous junction of the prelabium all the way around the latter vermillion of prelabium is turned backward. Vermilion border flaps of lips are formed. Small relaxation incision at base of ala.

Fig. 110: Formation of lip. Note backing of center part of vermillion by use of hinged vermillion of prelabium.

just posterior to the outer border of the columella and extended upward, almost to the juncture of the ala (Fig 114) The lateral incision is made on the inside of the ala, in a way similar to that described on p. 225 Both incisions are connected with each other just below the original vestibular hole (Fig 114) Two turnover flaps are now formed, as described on p 227, and are sutured together (Fig 115)

Fig 115 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

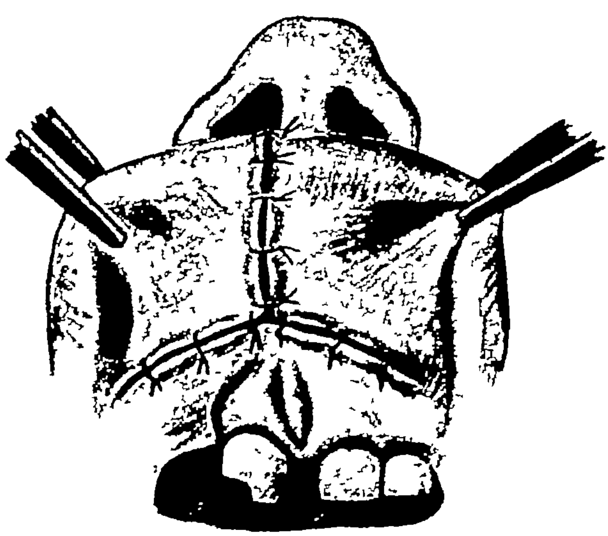


Fig. 116 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

Technic (Axhausen) The scar at the lip is excised a short incision is made along the mucocutaneous junction of the vermilion (Fig 111) With one branch of a pair of straight scissors inserted through the vestibular hole into the nasal cavity the remainder of the lip is severed The result is depicted in Fig 113

Two incisions are made upward from the upper edge of the wound for formation of the floor of the nostril The median incision is made

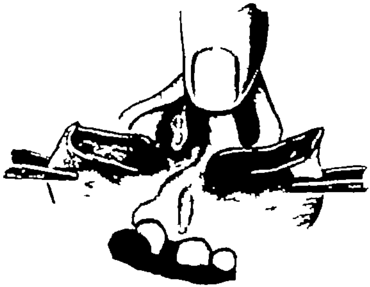


Fig 113: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

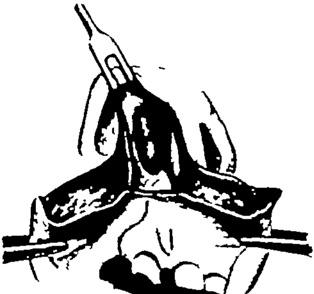


Fig. 114 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

border) *is missing* and the lip looks flat, Pickrell et al advise the subcutaneous insertion of a folded free fascia or dermal graft or a tendon graft (for example, of the musculus palmaris or the musculus peroneus brevis) above the vermilion border

Lateral displacement of the ala is corrected by excision of a strip of skin from the floor of the nose, reaching from the displaced alar tip to and above the tuberculum at the columella, a small, similarly shaped alar

Figs 118, 119 Repair of secondary cleft lip deformity with quadrangular flap method (compare with Figs 85, 86, 95, 96) A rectangular lip vermilion notch on the median side is filled with a quadrangular lip-vermilion flap from the lateral side. The scar above is excised wedge-shaped through full thickness of lip The apex of the wedge is within the floor of the nostril.

flap is formed, which is shifted into the defect and sutured in place. To facilitate the sliding of the flap, a triangle of skin is removed at the inside and outside near the base of the ala This also counteracts puckering of the skin If the *ala is flat,* a crescent-shaped piece of skin and cartilage is removed from the junction of the ala and the columella, followed by suturing of the skin (Fig 96) The tip cartilage may present a variety of deformities, as shown by the analysis of Huffman and Lierle A *flat ala with a wide alar-columella angle* may be simply repaired by the method of Steffensen An internal alar incision is made inside the nostril margin down the full length of the columella The cartilage is bluntly dissected free from the covering skin One scissors blade is placed between the cartilage and skin where the lateral crus should normally bend to join the median crus while the other blade closely hugs the septum Cartilage and lining are cut as far as the distal end of the bone, and the cartilage is then repositioned. It may be necessary to remove some cartilage from the dome if there is an excessive amount of cartilage and lining extending below the incision The wound edges are approxi-

The next step is mobilization of the soft tissues median and lateral to the cleft from incisions along the gingivolabial sulcus and advancement and suturing of the mucosal flaps (Fig 115) The formation of an alar flap as already described (p 227) now follows The tip of the flap is sutured in the upper corner of the wound behind the columella The posterior edge of the flap is connected with the turnover flaps, the anterior border with the anterior edge of the wound at the columella.

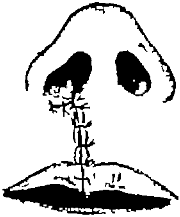


Fig. 117 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

Two small vermilion border flaps are made and the lip is sutured together in layers (Fig 117)

Since the quadrangular flap method (after Hagedorn LeMesurier) has come in vogue (compare with pp 220 223) attempts have been made to utilize this method in repair of secondary cleft lip deformities (Trusler and Glanz, Brauer) Hence in suitable cases it is possible to combine the Axhausen technic with the quadrangular flap method of lip repair (see Figs 118 119)

Technic in Minor Deformities with Absence of Connection between Vestibulum and Nasal Cavity In cases in which some of the foregoing deformities are not marked and in which there is no connection between vestibulum and nasal cavity correction of the outstanding deformities is done without reopening the cleft

If the *vermilion border edges are displaced upon one another* only a Z plastic operation is necessary (compare with Fig 163) A *notch in the lip* is overcome by a diamond shaped excision of the notching part of the vermilion border and closure of the gap in layers or in suitable cases the technic of Figs. 118 119 has much to be recommended great care is taken to accomplish exact adaptation of the mucocutaneous juncture of the vermilion If the *pout of the lip* (the bulge at or above the vermilion

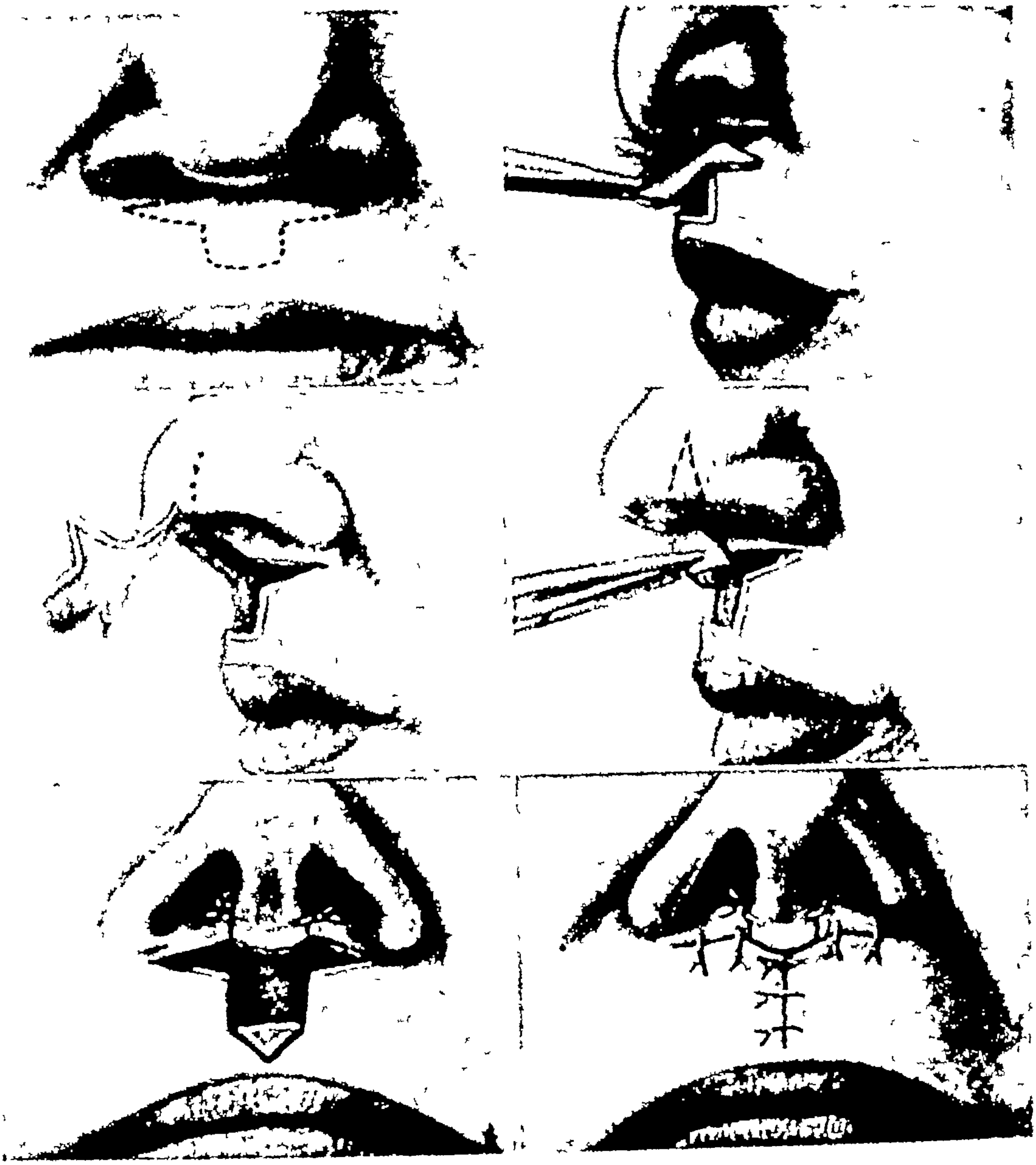


Fig. 120, *a*: Elongation of columella in secondary correction after repair of bilateral cleft. Design of flap to be advanced from upper lip, flap has lateral triangles to fill opening in septum and to allow for shortening of lip.

b. Flap is raised.

c. Membranous septum has been severed, area over nasal tip has been freed, incisions are made into mucosa high up over septum.

d. Flap being sutured in place, lateral triangles of flap are sutured into triangular defect over septum.

e. Flap in position at right angle to lip.

f. Lip is closed by shifting it to midline. No sutures should be inserted at base of columella to prevent dragging down the latter.

(J. B. Brown and F. McDowell, Ann. Surg.)

mated with one or two sutures. The nostril is lightly packed and molded into proper shape. If the *columella is displaced downward*, its base is circumscribed by a V-shaped incision and severed the lower angle of the V-shaped wound is sutured changing the V into a Y and the base of the columella sutured into the upper part of the Y thus shifting it to a higher level

Marked nasal deformities with asymmetry of heights of the tip cartilage cannot be corrected with simple procedures and a complete rhinoplasty is necessary at a later date The Réthi incision in these cases is of great value (see Fig 196) Gelbe exposes the underlying cartilages from a similar type of incision and attaches the flattened tip cartilage to the other side He then drapes the skin over it and adjusts it by excision of Burow type of skin triangles from either side of the tip (see pp 327–328)

If the *upper lip is retruding*, increase of the upper sulcus with an inlay skin graft is advisable (see pp 280 339) If the upper lip however, is too short it should be lengthened after the Estlander method by rotating a vermilion border lip flap from the middle of the lower lip into the upper lip (see p 191) or with the Dieffenback Webster cheek-sliding operation (compare with discussion on p 247)

In secondary corrections after repair of a bilateral cleft, main attention must be paid to overcome the *shortness of the columella*. Brown McDowell s suggestion is a good one The various steps are depicted in Fig 120 The columella is constructed by shifting part of the prolabium from the lip into a position below the septum after the entire area over the tip has been freed and the membranous septum has been severed The incisions into the mucosa high up over the septum are made. which open up in little "darts and allow elevation of the tip Now the little triangular darts that have been raised from the floor of the nose and left attached to the prolabium can be placed into the little darts opened up at the tip The only necessity is that the new columella should make practically a right angle with the lip and care is to be taken that the elevated prolabium is not sutured back down into the lip, with the production of an ugly web Occasionally insertion of a costal cartilage strut is necessary to prevent the columella from retreating too far into the nose The defect at the lip is closed (1) by shifting it clear over to the midline without putting sutures into the new columella, which would drag it down on the lip (Fig 120 *f*) or (2) by transplantation of a full thickness graft. The author has seldom found (1) possible unless it is combined with the Dieffenbach Webster cheek-sliding operation (p 200) (2) in two stages is preferred The first stage consists in

which are pedicled in front and back Bridge flaps had been used by numerous surgeons preceding Langenbeck (Dieffenbach, 1826, J. M. Warren, 1841, and others), for historical facts the reader should refer to Dr Dorrance's excellent book, "The Operative Story of Cleft Palate" It was Langenbeck (1861) who based the operation on sound principles, thus improving results and popularizing its merits Operators preceding Langenbeck failed to realize the value of including the periosteum in the flaps Langenbeck took the courageous step of including it—courageous since, according to the teaching of that time, to deprive a bone of its periosteum must inevitably lead to necrosis of the bone Including the periosteum in the flaps secured the circulation in them

In 1931 appeared the monumental work of Veau and his pupil, Plessier, which was to break with the principles of the classic operation of Langenbeck Veau's criticisms of the bridge-flap principle were sound He criticized it as resulting in a dropping and flattening of the palatal arch, in the creation of a dead space above the flaps, and in cicatricial changes of the flaps with consequent contracture and shortening of the soft palate. Veau considered the principle of the bridge flap as the sole cause of the imperfections He believed that mobilization and approximation of two lateral bridge flaps inevitably lead to a drop from their levels, particularly so if, for better mobilization, the nasal mucosa at the posterior edge of the hard palate is severed. Hence, the two flaps are hanging free in the oral cavity, anchored only on the anterior and posterior pedicles This creates a deep wound sac above the flaps, which becomes particularly hazardous since the nasal side of the flaps, deprived of mucosa, is raw and discharging The stagnation of the wound secretion may lead to infection, endangers the suture line, and leads to cicatricial changes and shortening and thickening of the palatal flaps and muscles

To eradicate these disadvantages, Veau developed a technic which is based on the following principles formation and median displacement of single-pedicle flaps (pedicled posteriorly) of the palatine mucoperiosteum, mobilization and suturing of the nasal-mucosa flaps, anchoring of the palatine flaps to the nasal mucosa with mattress sutures, and approximation of the separated palatine muscles

The Veau operation has not remained unchallenged Its chief adversary became Lexer, for whose conversion Veau devoted much space in his work, but Veau gradually achieved recognition of the principles of his procedure all over the world.

Axhausen, well acquainted with the Veau procedure and acknowledging its great merits, felt that Veau was nevertheless in error to indict the Langenbeck bridge flaps, per se, as the cause of failures, Axhausen attrib-

raising the skin of the prolabium and returning it. After four weeks (i e, after development of an adequate circulation in the prolabium flap) the main operation is performed Before placing the full thickness graft (taken from the supraclavicular region) on the lip the wound edges of the lip are pulled slightly together with two horizontal mattress sutures of fine chromic catgut This inevitably raises the wound edges and depresses the center of the raw surface to the degree of a normal philtrum The raw area is then covered with the graft, which is sutured in place The sutures are left long and are tied over the pressure dressing (For results see Case 35 p 894)

In cases of *dog mouth deformity* which is due to a forward displaced premaxilla (see p 233) the premaxilla must be removed this is usually done just before the child goes to school or even earlier The bone of the premaxilla is exposed by submucosal dissection It is essential to make the anterior (gingivolabial) flap as long as possible i e., to include all the anterior mucosa of the premaxillary bone After excision of the premaxilla which is done with chisels and bonecutters this flap makes an excellent lining of the anterior gingivolabial sulcus which is often shallow and can now be deepened with this flap the flap is sutured to the posterior lining of the excised premaxillary bone. As soon as the wounds have healed a removable prosthesis should be applied to the upper teeth to replace the front teeth and particularly to keep the upper lip forward as in a normal profile (For results see Case 35 p 894)

If a *lengthening of the columella* is also planned excision of the premaxilla as described in the foregoing paragraph and the first stage columella lengthening (i e raising and returning of the prolabium flap) can be combined

In cases with *loss of tissue and flatness of the lip*, a vermilion border lined flap is rotated from the middle of the lower lip into a center split of the upper lip (Estlander Abbé) (see Fig 67) This seems to be the popular method However the Dieffenbach Webster cheek sliding operation (see p 200) should first be given a trial before switching the Abbé flap which is really not more than an interposed piece of lip without function *Vertical shortness of the lip or obliteration of the gingivolabial sulcus* is overcome by inlay skin-grafting (see pp 280 339)

Cleft Palate

For time of operation and preoperative treatment see p 217

Choice of Operation The classic operation for closure of a cleft palate is the so-called von Langenbeck operation Its principle is the median displacement and approximation of lateral palatine bridge flaps

anterior clefts where the vomer is too short and vomer flaps are not available This is also true for short palates requiring a pushback operation (p 268)

The operation will be described in detail for a cleft involving the soft and posterior part of the hard palate Axhausen recommends local anesthesia (the author uses general anesthesia). A small pillow is placed beneath chest and shoulders to allow a backward bend of neck and head The mouth is held open with a Lane or other type of spreader, the tongue—if necessary—is grasped with a towel clamp or suture and held forward Instruments to be used are fine but simple, and are depicted in Fig 76

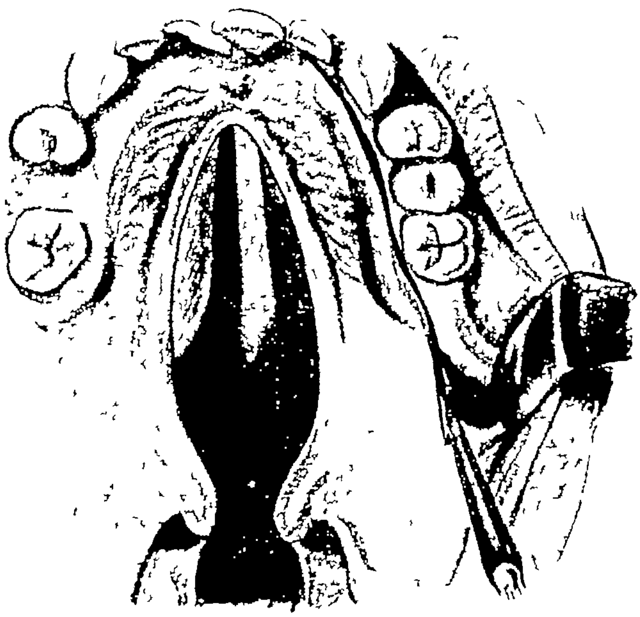


Fig 121 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

CLEFT OF SOFT PALATE AND POSTERIOR PART OF HARD PALATE

Technic (Langenbeck-Axhausen). *Formation of Lateral Bridge Flaps* The operation starts with the lateral relaxation incision on the left side Anteriorly, the incision commences somewhat in front of the level of the anterior cleft angle (Fig 121), and runs along the alveolar process until the posterior edge of the process is reached The incision, following the same direction and slightly more laterally, is continued into the soft palate (Fig 122) for about 1 5 to 2 5 cm (5/8 to 13/16 inches)

With a small periosteal elevator, the mucoperiosteum median to the incision is elevated from the bone The position of the tip of the instrument should be checked with the thumb of the other hand (Fig 122). The mobilization is extended to the median border of the cleft—but

uted these failures to the lack of proper mobilization of the bridge flaps. He modified and improved the Langenbeck operation by including modern principles as brought forward by Veau Wardill Ernst, and others. To prevent the bridge flaps from dropping from their levels—which was thought by Veau to be the inevitable imperfection of the classic operation—Axhausen introduced two important features (1) The flaps were more thoroughly mobilized hence, the flaps gained in length (2) The nasal mucosa at the posterior edge of the hard palate was not severed together with the aponeurosis along the bony edge (as in the classic operation of Langenbeck) but carefully freed from the bony edge and left in continuity with the mucosa of the soft palate The method found many enthusiastic followers (Schuchardt and others) it became known in the United States mainly through the publication of Ivy and Curtis who consider it as a further advance in palatine surgery The author is in full accord with their experience

Recent research (see p 218) on facial growth (Graber Slaughter and Brodie Waldron) has influenced our views on cleft palate correction Formerly we were all too much concerned with the technical details of closing the cleft, and neglected or overlooked a most important problem that still remained—maldevelopment of the maxilla with consequent malocclusion and functional and cosmetic handicaps which too often followed the conventional types of cleft palate repair The maxilla grows by sutural and surface deposition of bone. The growth is arrested if the blood supply is impaired. This may happen if the maxilla is denuded of its periosteum after periosteal elevation as it is frequently done in the surgical repair of cleft palate. To prevent interference with growth one must either delay closure or avoid procedures that might interfere with growth *In the majority of cases delayed closure is not advisable* since not all cleft palate operations with early closure result in interference with maxillary growth particularly in the closure of partial posterior clefts furthermore delayed closure may cause a permanent speech impediment. Since interference with growth seems to be directly proportionate to the amount of injury to the growth centers of the maxilla by diminishing the blood supply avoidance of injury to these growth centers—that is avoidance of extensive elevation of the mucoperiosteum of the hard palate—is an objective to be preferred over the mere negative one of delaying the closure This can be readily accomplished in closures of partial posterior clefts in unilateral clefts by extensive use of a vomer flap (Waldron Dunn) (see Figs. 143-145) and also in those large clefts in which bilateral vomer flaps can be used. Reasonable delay of closure is advisable however until the child is about *five years of age* in large

by stripping off all the overlying tissue with a piece of gauze Exposure of the tendon is important, since it is the path along which the mobilization of the soft palate is carried out To avoid protrusion of the fat pads of the cheek, care should be taken not to penetrate too far laterally If protrusion occurs, the fat should be retracted and the tendon localized more mediad Median to the tendon one finds the space which surrounds the pharyngeal organs. This space can easily be opened up beyond the

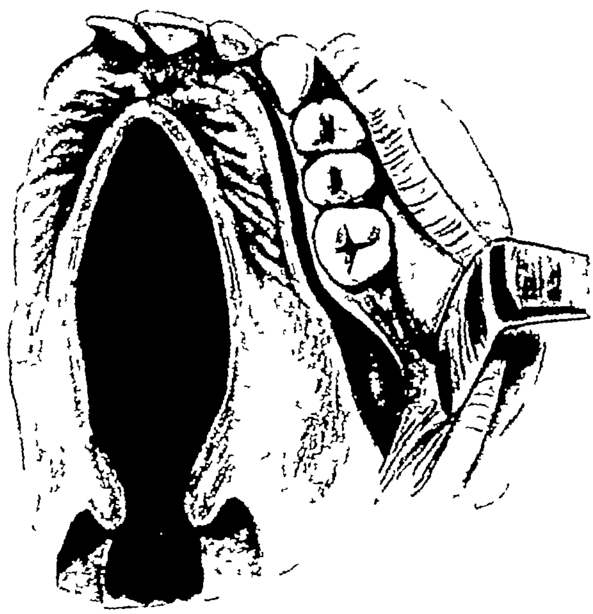


Fig 124 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

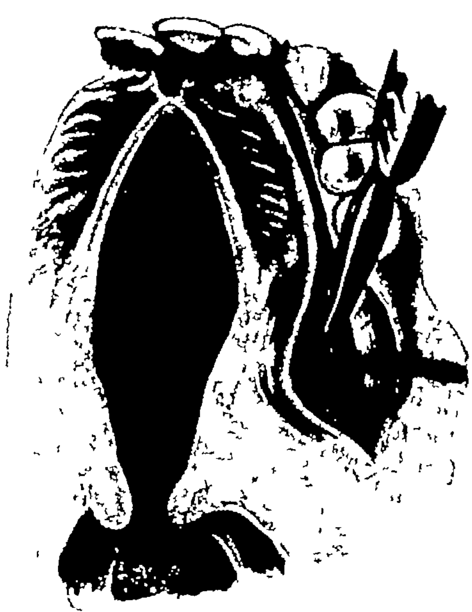


Fig 125 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen.

should not perforate the mucosa at this point—and to the posterior edge of the palate In front of the cleft undermining is extended beyond the midline and close to the cleft angle (Fig 123)

Mobilization of Soft Palate The next step is mobilization of the soft palate A retractor is inserted into the lateral wound region (Fig 124) and the wound deepened by spreading a pair of dissecting scissors until the glistening tendon of the musculus pterygoideus internus is visible (Fig 124) Sometimes visualization of the tendon may be facilitated

Fig. 122 G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München

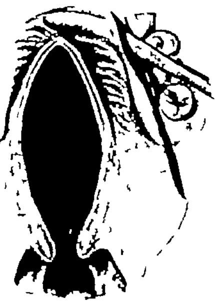


Fig. 123: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

is clearly visible Median to it one finds the hamulus, either close to the tendon or somewhat in front of it The best way to locate the hamulus is to lead a small elevator along the pterygoid tendon, forward and upward, until the bony insertion is felt If the instrument is now pushed mediad, the resistance of the hamulus is palpable After dissection of the hamular process with the elevator, one sees the tensor veli palatini extending obliquely over it into the soft palate A small chisel is placed in front

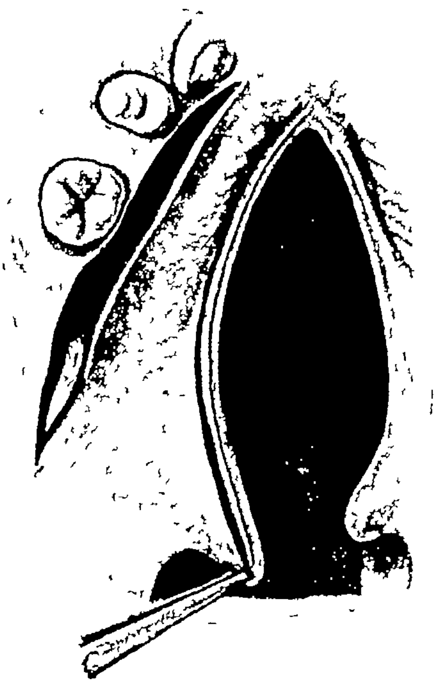


Fig 128 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

of the tendon (Fig 126) and the hamulus severed, thus allowing the tensor tendon to be displaced mediad and relaxing the soft palate (Fig 127) Median to the hamulus stump is the posterior rim of the hard palate, which is now freed from muscle and fibrous tissue

As the next step, Axhausen advises ligation and separation of the arteria palatina for better mobilization of the bridge flap The author has found no advantage in this procedure, since the flap can be stretched sufficiently, as described on p 272 Indeed, severance of the arteria palatina may be a disadvantage if additional procedures, such as a pushback operation (Fig 156), are required later on

The same procedure is carried out on the right side

Preparation of Cleft Margins The incision is made on the right side, starting just above the cleft angle, and is led parallel to and somewhat away from the cleft margin (Fig 128). The line of incision is marked by nature, it is the line where the pale mucosa of the margin joins the darker mucosa of the palate proper (Fig 121)

tonsil to the cervical spine either with an elevator or with the finger The lateral pharyngeal wall (soft palate, pillars and tonsil) is displaced mediad (Fig 125) until it touches the opposite side. The space is temporarily packed with plain gauze

Middle Portion of Incision Attention is now paid to the middle part of the incision where the flap is still firmly attached to the posterior edge of the palatine bone. The flap is severed from the bone bluntly or under sharp dissection until the insertion of the pterygoid tendon to the bone

Fig. 126: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München

Fig. 127: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

used only after the connecting fibrous bands have been separated with the knife (Fig. 131). At the posterior edge of the palatine bone, the small bony process (spina nasalis posterior ossis palatini) is reached, from which the insertion of a tiny muscle bundle is severed (Fig. 131). The elevator can now be led around the posterior bony edge.

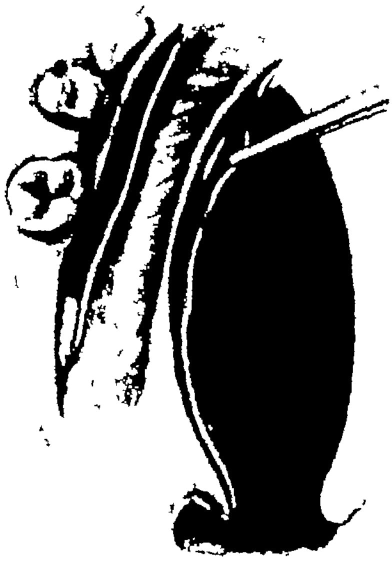


Fig. 130 G. Axhausen: Technik und Ergebnisse der Spaltplastiken C. Hanser, München

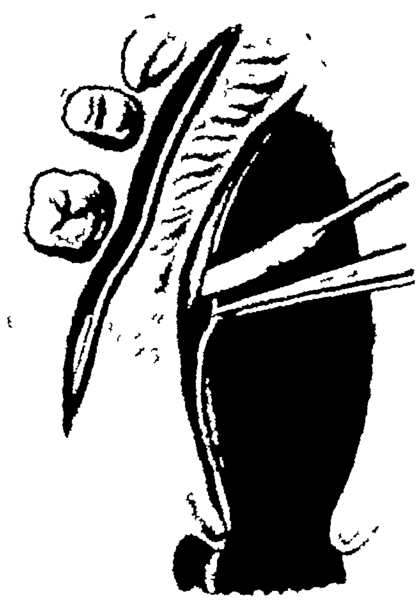


Fig. 131 G. Axhausen: Technik und Ergebnisse der Spaltplastiken C. Hanser, München

Mobilization and Formation of Nasal Mucosa Flap: Mobilization and formation of the nasal-mucosa flap are now carried out. With the small, curved elevator, the nasal mucosa is elevated from the nasal side of the palatine bone, starting posterior to the bony rim of the palate and grad-

The knife is led along this line upon the bone until the posterior edge of the hard palate is reached The uvula is now grasped with a forceps and the margin of the soft palate cleft incised longitudinally The incision starts near the uvula and in front joins the first incision The uvular margin is incised in the same way and the tip is split with a pair of scissors

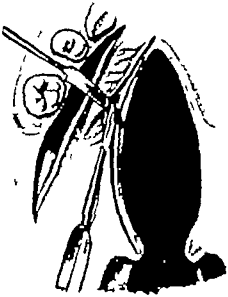


Fig. 129 G. Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

From the marginal incision the mucosa of the hard palate is split into two layers nasal mucosa and oral mucosa Mobilization of the nasal mucosa is the most difficult part of the procedure. Partly under blunt, partly under sharp dissection the median wound edge at the margin is severed from the oral surface of the palatine bone until the bony margin itself is reached (Fig 129) The mucosa is now carefully mobilized from the bony edge. This is best done with the knife which at all times must remain in contact with the bone Gradually the pale-colored edge of the bone becomes visible. The edge of the mucosal wound is now grasped with a pair of forceps and pulled into the cleft (Fig 130) thus permitting visualization of the remaining connecting fibrous bands which must be severed with the knife A small curved elevator such as dentists use (Fig 76 lower row second from left) can now be led around the bony edge submucously to the nasal side of the bone.

At this point, one may be tempted to push the instrument forward and backward to free the nasal mucosa This may however tear the mucosa and in this location a rent is apt to enlarge rapidly Hence the same procedure should be followed as on the oral side and the elevator

The left side of the palate is now prepared in the same way as the right side, in front completing the anterior commissure on the oral as well as on the nasal side Mobility of the bridge flaps is now checked, and should be such that both can be easily approximated in the midline

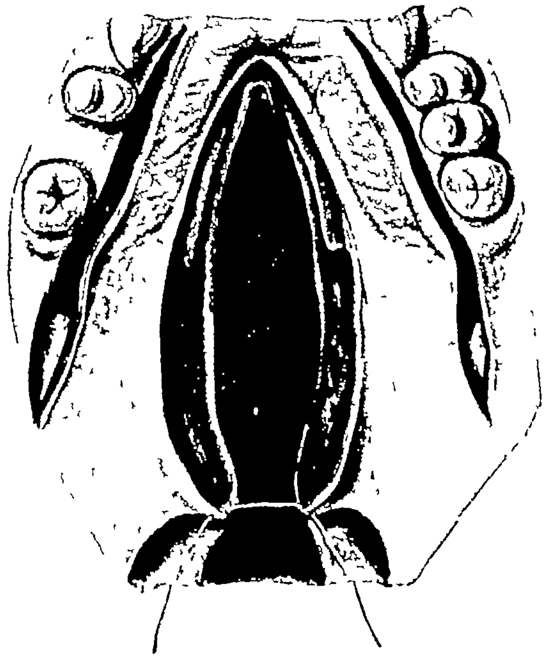


Fig 134 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

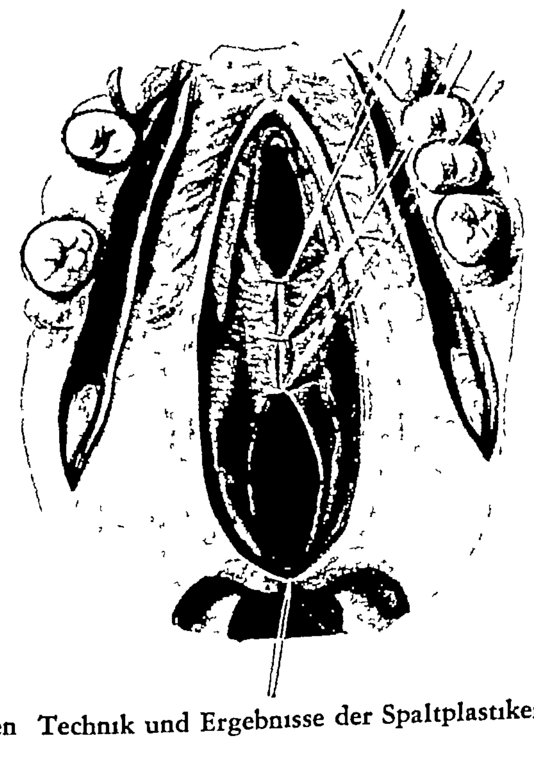


Fig 135 G. Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, München.

ually working forward until a broad nasal mucosa flap is formed which if pulled mediad easily reaches the midline

From the marginal incision of the soft palate, the latter is split in layers The oral mucosa is severed from the musculature with knife and

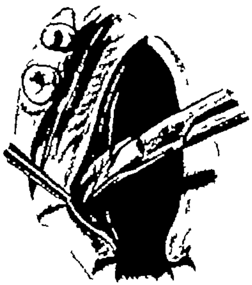


Fig. 132: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

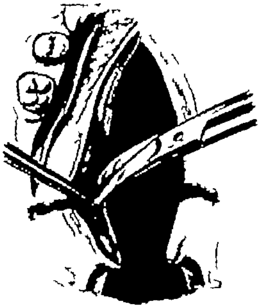


Fig. 133 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

scissors (Fig 132) The uvula itself is dissected in the same way Muscles and oral mucosa are retracted and the nasal mucosa severed from the muscles (Fig 133) until the muscle layer is clearly visible as a separate layer thus permitting a separate suture

Suture of Flaps Approximation of the nasal mucosa is carried out first, and starts wth suture of the uvula tip (Fig 134), followed by sutures of the middle part, 00000 chromic catgut is used, and the sutures are left long for traction (Fig 135). The remainder of the sutures can be inserted without difficulty

Fig 139 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, München

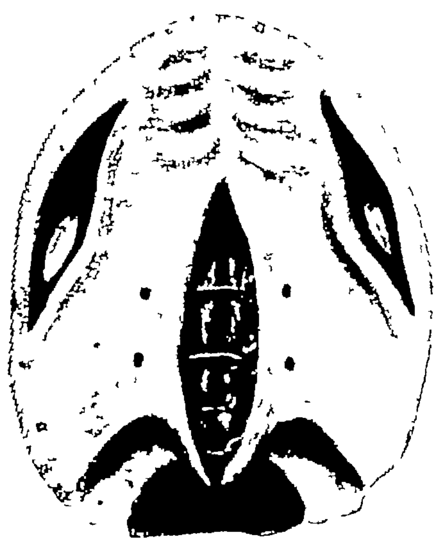


Fig 140 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, München

The muscles of the soft palate are united with two or three sutures of 000 chromic catgut as demonstrated in Figs 136 to 140

Approximation and suture of the oral bridge flaps now follow If the assistant pulls the uvula posteriorly by grasping the uvular traction

Fig. 136: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

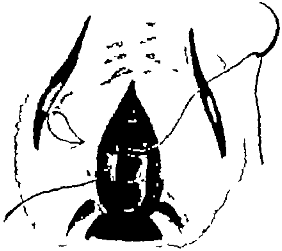


Fig. 137: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

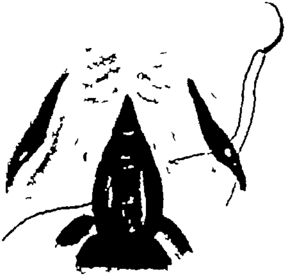


Fig. 138: G Axhausen: Technik und Ergebnisse der Spaltplastiken. C. Hanser München

swallow without difficulty (three to four days postoperatively) After the temperature has returned to normal, the patient is allowed to sit up and to be out of bed The patient is discharged eight or ten days after operation

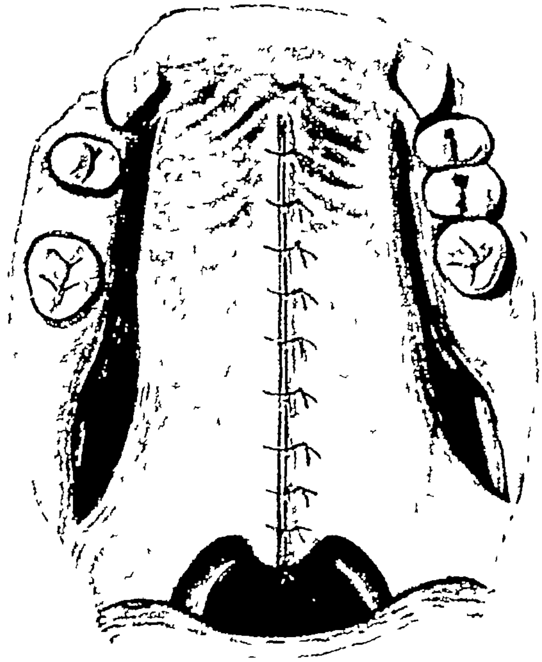


Fig 142 G Axhausen Technik und Erbegnisse der Spaltplastiken C Hanser, München

UNILATERAL CLEFT PALATE

In this form of cleft, the cleft reaches in front between the processus maxillaris on the lateral side and the vomer on the median side The vomer is attached to the processus palatinus, hence, only one half of the nasal cavity is open A typical example is the through-and-through cleft-lip-cleft-palate case in which the lip and alveolar clefts have been closed previously, as depicted in Fig 143. Again the improved von Langenbeck operation is performed At the vomer, however, a flap of mucoperiosteum is made and turned over to the lateral side, where it is attached to the palatal mucosa (Veau) For reasons already mentioned on p 249, the bridge flaps should not be carried too far anteriorly. Shifting a mucoperiosteal flap from the maxilla across and over the vomer flap is rarely necessary and is unwise from the standpoint of future growth (Waldron, Dunn).

Technic: The lateral incisions for formation of the palatine bridge flaps are similar to those described in the foregoing (Figs 121, 122), but they are not carried as far forward as demonstrated in these figures. Fig. 143 shows their approximate length. The development of the

suture approximation is facilitated. The posterior part is sutured first and then the anterior one (Figs. 141 142) care being taken that the wound edges are well adapted.

The temporary packings are removed Axhausen advises packing the pharyngeal pockets to keep the soft palate relaxed during the healing period We have seen no need for this

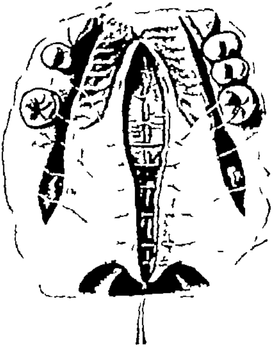


Fig. 141: G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

Axhausen Wassmund and Schuchardt now insert a celluloid plate which has been prepared preoperatively It is fastened to the upper teeth Its purpose is to hold the palatal flaps snugly against the roof of the palate. This prosthesis is changed frequently for cleansing and replacing a gauze pad which is placed upon the plate The gauze pad is later on replaced by a gutta percha plug This support is discarded after four or five weeks The author has found no need for this prosthetic after-care however in special cases the palatal flaps must be supported This is done either with the above-described method or with the simpler one described on p 268

After Treatment The patient is placed in bed on his abdomen and given *fluids* by clysis Antibiotics are administered Sterile water by mouth is given after nausea if the patient is able to swallow *In children* the arms are splinted as described on p 232 After the first twenty four *hours* the patient receives liquid diet including milk gelatine ice cream and the like. The diet is changed to soft foods as soon as the patient can

pharyngeal pocket and severance of the hamulus are similar to the steps depicted in Figs 124 to 127 On the median (closed) side, a turnover flap of the vomerine mucoperiosteum is now made (Fig 143). The borderline between the pale palatine and the dark-red vomerine mucosa is clearly visible An incision is made along this line, starting in front and connected in back with the incison along the margin of the soft-palate

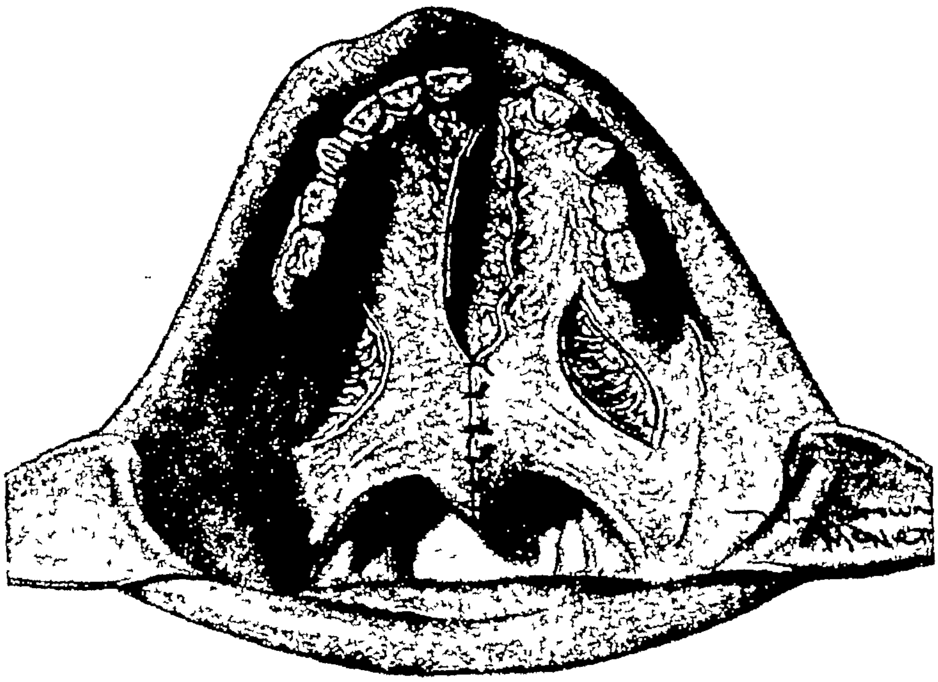


Fig 145 Closure of unilateral cleft palate with utilization of vomer flap Remainder of cleft closed as far anteriorly as possible

cleft The vomerine mucoperiosteum is elevated This is not difficult in front, but at the posterior rim, great care should be taken not to sever the vomerine mucosa from the nasal mucosa of the soft palate The posterior osseous connection with the posterior edge of the hard palate is dissected free with the knife, and the muscular and fascial attachments of the spina nasalis posterior ossis palatini are severed until the small elevator can be led around the posterior rim of the hard palate to the nasal side To obtain free motility of the vomerine nasal-mucosa flap, the posterior rim of the vomer must be freed submucously (Fig 144) The margin of the soft palate is split in the usual way (compare with Figs 132 to 133)

On the lateral side of the cleft, an incision is made along the rim of the hard palate, and the mucoperiosteum of the margin is elevated for about 2 or 3 mm (Fig 144) The vomerine mucoperiosteal flap is now

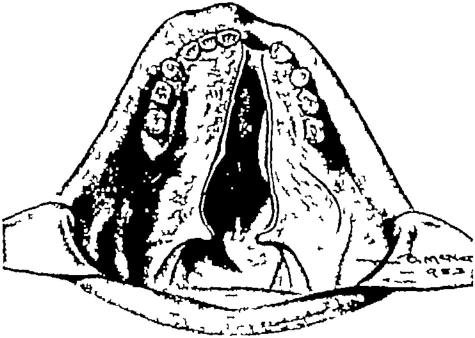


Fig. 143: Closure of unilateral cleft palate with utilization of vomer flap incisions are lined out.

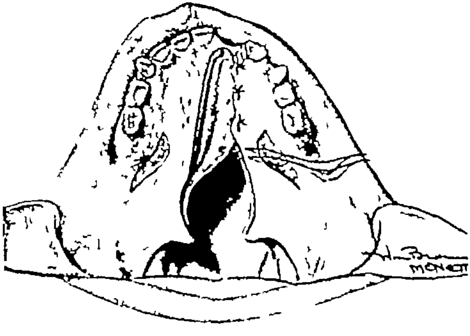


Fig. 144 Closure of unilateral cleft palate with utilization of vomer flap. Vomerine flap turned over to be tucked beneath lateral mucoperiosteal flap with "vest-over pants" type of mattress sutures.

Technic: (in Cases with Underdeveloped Vomer). *Stage 1* The posterior part of the palate is closed as described on p 250, it is emphasized that the palatine arteries should not be severed or ligated but stretched as described on p 272 The cleft is closed as far anteriorly as it is possible without causing tension of the flaps

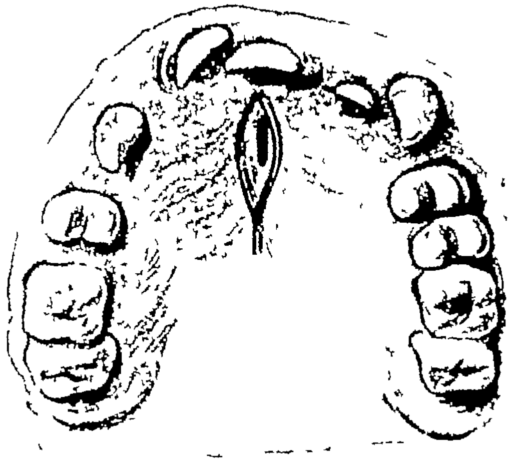


Fig 146 G Axhausen, Technik und Ergebnisse der Spaltplastiken C Hanser, München

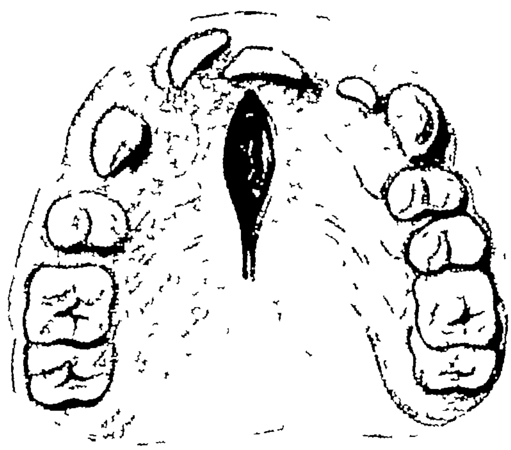


Fig 147 G Axhausen Technik und Ergebnisse der Spaltplastiken C Hanser, Munchen

Stage 2: The anterior hole (often larger and longer than depicted in Fig. 146) is closed after four or five weeks The rim of the hole is circumscribed with an incision which is extended posteriorly for a short distance (Fig. 146) The incision should penetrate deep enough but not through the whole thickness of the tissues. A bilateral turnover flap is made and hinged inward (Fig. 147). Two single-pedicle lateral flaps are now made, which are to be shifted mediad (Fig 148). The undermining for mobilization of the flaps should start from the median side. The oral mucosa is severed from the nasal mucosa until the palatine bone is

turned over to the lateral side and sutured beneath the elevated periosteal surface of the lateral mucoperiosteum with three mattress sutures of the vest-over pants type (Fig 144 see also p 467) At the posterior rim the vomerine flap passes gradually over into the nasal mucosa of the soft palate which is sutured to the other side The following steps are the same as described (Fig 145 compare also with Figs. 134 to 141)

After Treatment See p 261

BILATERAL CLEFTS

The term bilateral cleft of the palate may not be quite correct but it is descriptive In this type of cleft there is no connection between the vomer and the palatine process (compare with foregoing paragraph) the oral cavity communicates with either nasal cavity the vomer hangs free in the middle To this group belong the extensive postalveolar clefts (Group 2 of the classification of p 216) and the bilateral through and through lip palate clefts (Group 3) The type of closure of these bilateral clefts depends upon the condition of the vomer i e whether the vomer is fully developed or rudimentary and short In the former case closure can be accomplished in one stage while, in the latter case two stages are required A typical example of closure of the former type (i e. with fully developed vomer) is the repair of the bilateral cleft of a case of through and through lip-palate cleft in which the lip and alveolar clefts have been closed previously (see also p 232)

Technic (in **Cases with Fully Developed Vomer**) The operation is similar to that described for closure of unilateral cleft palates in which much use is made of a vomer flap (see Figs 143–145) the only change being that the mucous membrane of the vomer—the vomer hangs free in the middle—is split upon the vomerine ridge and a flap of mucoperiosteum is reflected on either side of the vomer and turned over to the lateral sides where they are tucked beneath and attached to the palatine mucosa as in the unilateral type and depicted in Fig 144 The vomer bone is left denuded to granulate and heal

A typical example of closure of a bilateral cleft palate in which the vomer is rudimentary or absent is closure of an extensive postalveolar cleft which extends far anteriorly The operation is divided into two stages. In the first stage, the posterior part of the cleft is closed in the second stage the anterior part is closed However it should be emphasized that in this type of cleft palate the operation should be delayed until the child is five years of age This operation requires extensive denudation of the hard palate this may result in disturbance of its growth centers if the operation is carried out too early (see p 249)

reached Mobilization can then be completed from the lateral side, starting from the lateral side may tear the nasal mucosa The base of the pedicles of the flaps should be in level with the posterior point of the median incision Mobilization, however, should be carried farther back (Fig 148) To achieve perfect coaptation of both flaps in the midline, it is necessary to split the median wound edge (Fig 149) After the flaps are sutured together (Fig 150), they are held in place for one week with a piece of dental compound, which is softened in warm water, molded in place, and fastened with dental wires, these cross from one side of the dental arch to the other and are made to pass through the mold while the latter is still soft

CLEFTS ASSOCIATED WITH SHORT PALATE

In this type of cleft, not enough tissue is present to achieve sufficient length of the palate posteriorly Hence, the nasopharynx cannot be entirely closed by the patient Such velopharyngeal insufficiency causes a speech defect Various efforts have been made to achieve velopharyngeal closure (1) by posterior displacement of the palate (Halle, Limberg, Ernst, Dorrance, Wardill, and others), (2) by utilization of a flap from the posterior pharyngeal wall (Schoenborn, Rosenthal, Padgett, Sanvenero-Roselli, Moran, Dunn), (3) by a combination of both methods (Marino and Segre, Conway), or (4) by suturing the velum into the posterior pharyngeal wall except for small openings (Trauner)

Of the first group of operations, the so-called "pushback operation" of Dorrance is the most popular The mucoperiosteum of the hard palate is raised as a flap The palatine vessels are severed A free split thick skin graft is sutured to the exposed raw areas of the nasal aspect of the mucoperiosteal flap, and the flap is returned to its original site Later, the flap is raised again and pushed back all the way to the posterior rim of the hard palate where it is fastened with sutures, thus bringing the soft palate in contact with the posterior pharyngeal wall The gap is then closed

J B Brown offers a modification, which may permit a one-stage procedure Mobilization of the palate is carried out without separating, but freely loosening, the palatine vessels until they can be stretched far enough to permit a setback of the palate Limberg, Marino, and Conway remove the posterior wall of the bony palatine canal, thus freeing the neurovascular bundle from its bony environs and achieving a greater degree of palatal retrodisplacement

The posterior displacement operation of the palate can be performed in cases in which the cleft of the hard palate does not extend too far in front It is indicated as a primary operation in cases with definite short-

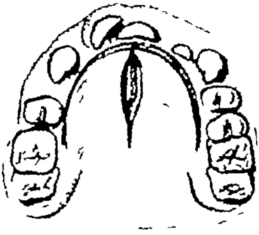


Fig. 148 G Axhausen Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

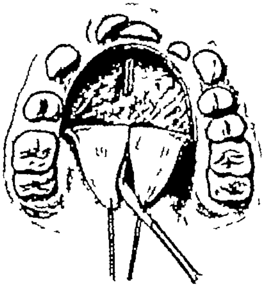


Fig. 149 G Axhausen, Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

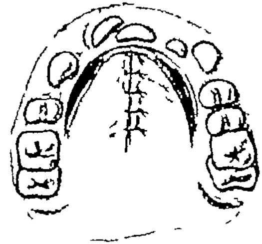


Fig. 150 G Axhausen, Technik und Ergebnisse der Spaltplastiken. C. Hanser München.

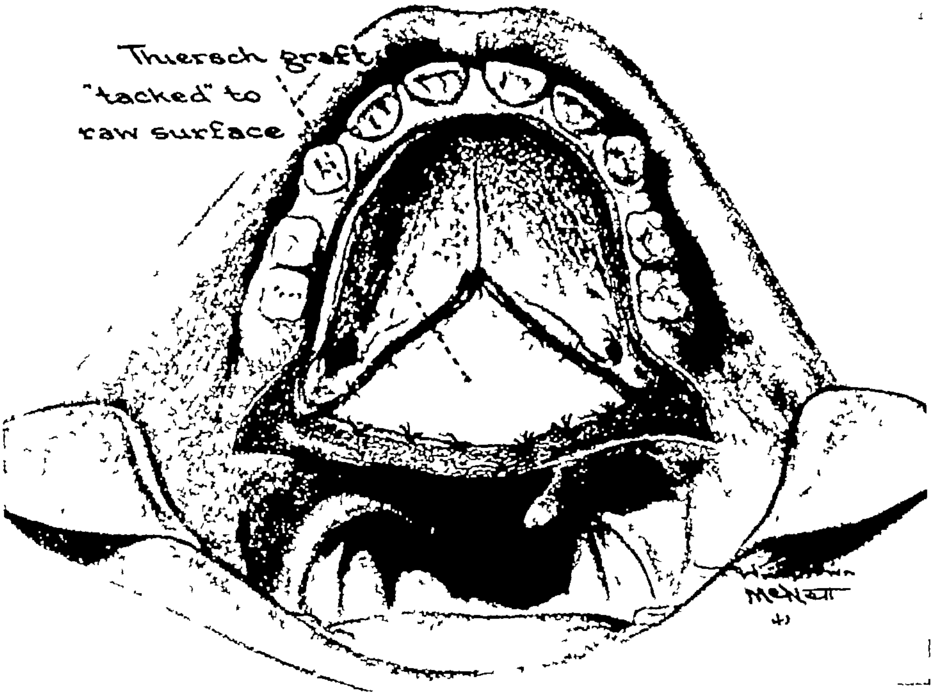


Fig 153 G M Dorrance and J W Bransfield Ann Surg

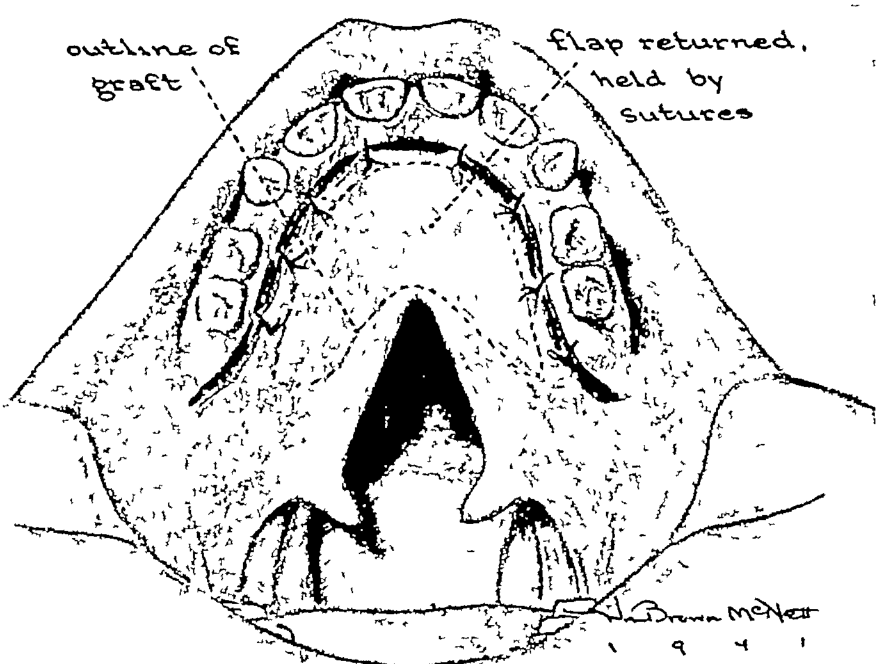


Fig 154 G M Dorrance and J W Bransfield Ann Surg

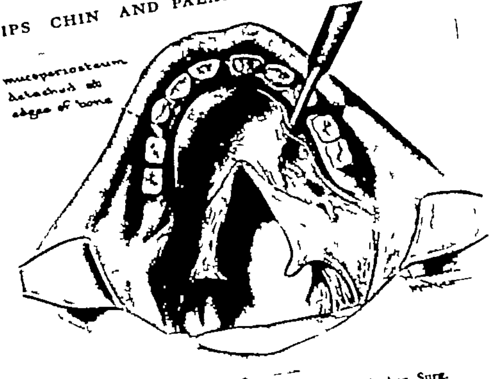


Fig. 151 G M. Dorrance and J W Bransfeld: Ann. Surg.

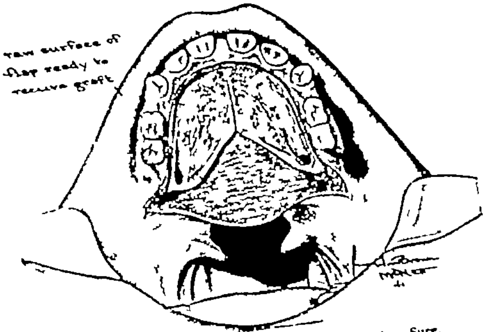


Fig. 152: G M. Dorrance and J W Bransfield Ann. Surg.

to the bone at the apex of the defect (Fig 155). The borders of the cleft are denuded Interrupted sutures are passed through the nasal mucosa but not tied, until the insertion of the intramuscular wire suture around the muscles, as in Veau's procedure. The interrupted sutures are then tied, followed by twisting the wire suture and approximation and suture of the oral mucosa

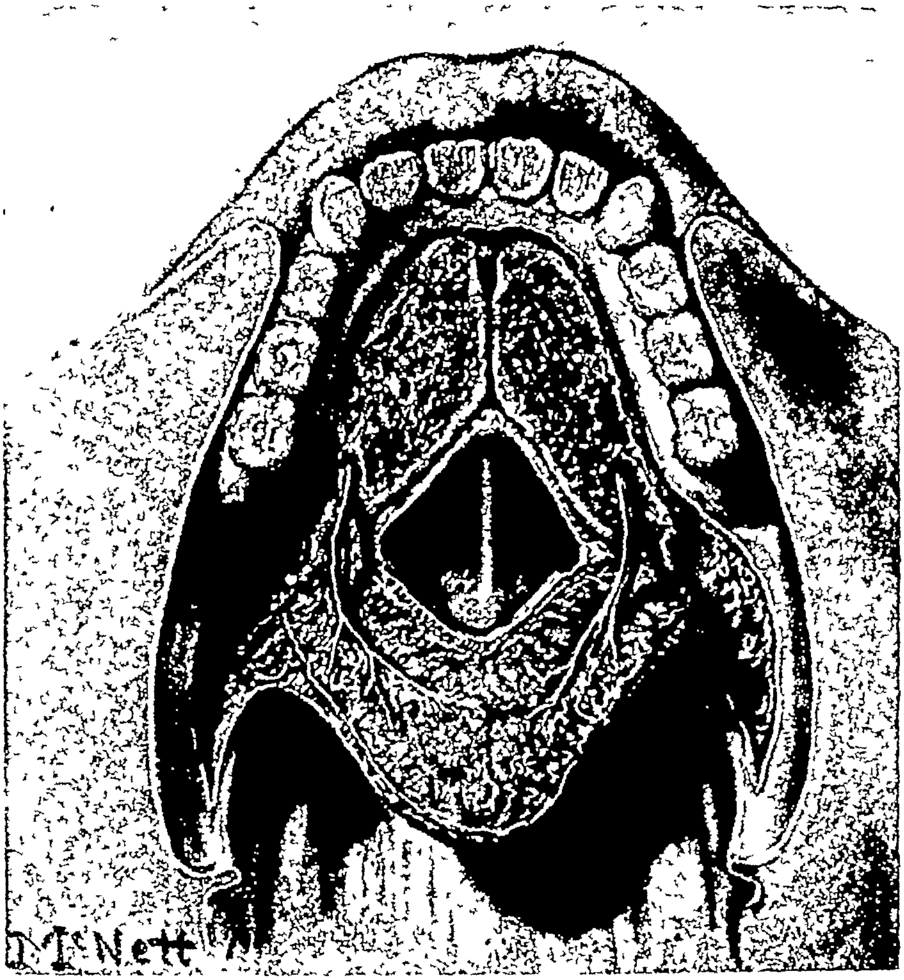


Fig 156 Elongation of partly cleft palate (after J B Brown) Flap of mucoperiosteum is raised from hard palate Major palatine arteries are gently stretched (Redrawn from J B Brown Am J Ortho & Oral Surg)

Technic (J. B. Brown): A flap of mucoperiosteum is raised from the hard palate, as just described The major palatine arteries are not severed but loosened of all tissue around them and gently stretched from the foramen and, if necessary, carefully dissected away from the flaps (Fig 156) Removal of the posterior wall of the bony palatine canal (Conway) may permit additional lengthening of the neurovascular bundle and favor a greater degree of retroposition of the mobilized palate The entire

ness of the palate and as a secondary operation where the first operation has resulted in velopharyngeal insufficiency The operation should not be performed until the patient has reached the age of five The operation requires extensive denudation of the hard palate this may disturb its growth centers if the procedure is performed too early (see p 249)

Technic (Dorrance s Pushback Operation) *Stage 1* Through an incision along the alveolar arch a flap of mucoperiosteum is raised from the hard palate (Figs 151, 152) The posterior palatine vessels are

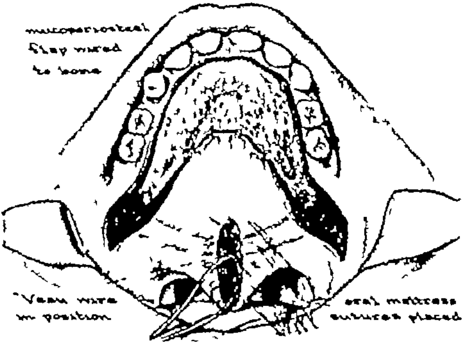


Fig. 155: G M. Dorrance and J W Bransfield: Ann Surg.

divided and the flap freed from its bed all the way back to the attachment of the palatine aponeurosis (Fig 152) A split skin graft is sutured to the raw surface of the flap (Fig 153) The flap is then returned to its original site and sutured (Fig 154) Pressure dressing is applied with dental compound as described on p 268

Stage 2 From three to ten weeks later—depending upon the color of the flap—the flap is again raised and the palatine aponeurosis and nasal mucosa freed from their connection with the posterior border of the hard palate. The hamular process is divided with a chisel The relaxation incisions are extended backward around the maxillary tuberosity and over the pterygomandibular fold freeing the palate from all bony attachments. The entire palate is now pushed back and the anterior portion of the flap sutured with four wire sutures to the fibrous membrane and

the desired speech, in spite of vigorous trials of speech-training. He advises not to delay the operation too long, an incompetent palatopharyneal sphincter may not respond quickly to thorough training exercises. It is better to achieve early improvement of the sphincter with a flap operation than to have the patient form poor speech habits with objectionable nasality Moran does not combine the pharyngeal-flap operation with the

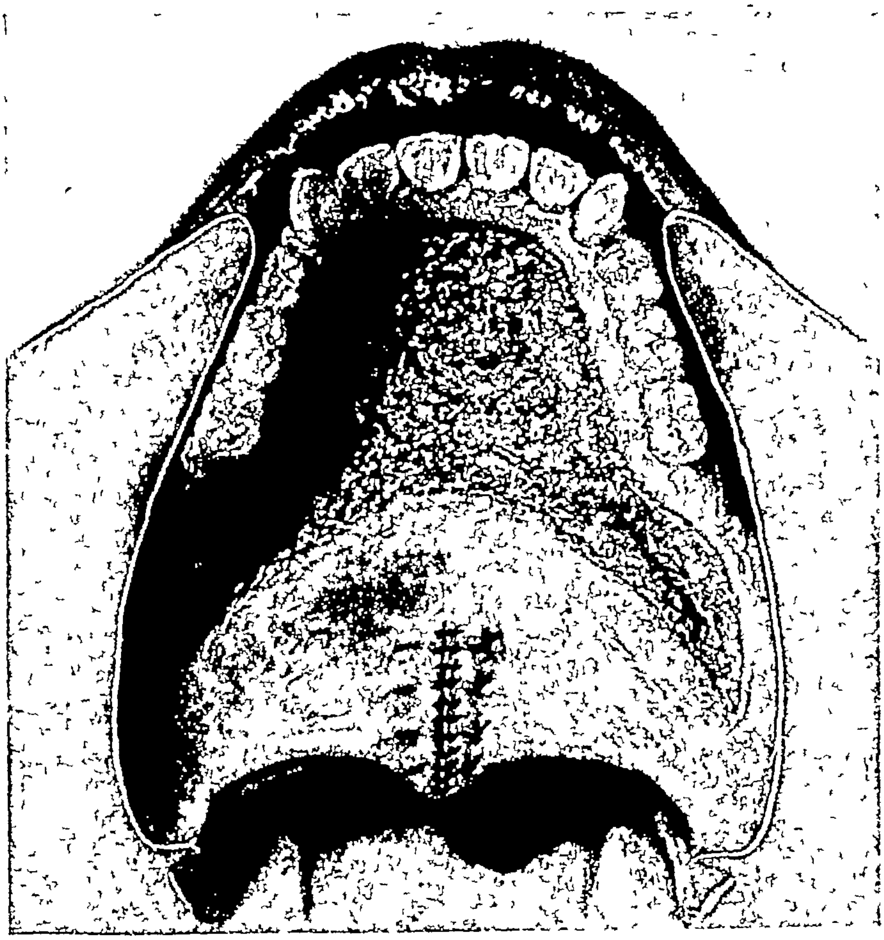


Fig 158 Elongation of partly cleft palate (after J B Brown) Closure of cleft can be performed in same stage or later (Redrawn from J B Brown Am J Ortho & Oral Surg)

pushback operation, since he considers it unnecessary in the majority of cases Conway, however, reports better results after the combined operation than after the pharyngeal-flap operation alone Rosenthal and Conway pedicle the flap downward, Padgett, Sanvenero-Roselli, and Moran pedicle it upward

Technic (Postpharyngeal Flap): The operation is performed under local or general anesthesia (endotracheal anesthesia through the mouth) The posterior pharyngeal wall is distended with procaine to facilitate dissection and to minimize bleeding The soft palate is retracted forcibly

mass of tissue is immediately set back and sutured to the posterior rim of the bony palate as described in the foregoing (Fig 157) The closure of the cleft can be performed in the same stage but if hemorrhage is excessive closure may be delayed (Fig 158)

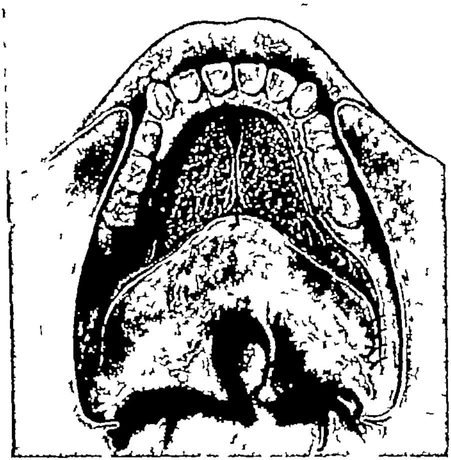


Fig. 157: Elongation of partly cleft palate (after J B. Brown) Entire mass of tissue is immediately set back and sutured to bony rim of palate (Redrawn from J B. Brown: Am. J Ortho. & Oral Surg)

Other Procedures In competition with the pushback operation and its modifications which often improve speech inadequately is the transfer of a postpharyngeal flap to the soft palate (Schönborn Rosenthal) Through the flap itself as well as through its pull the soft palate is lengthened and retrodisplaced without narrowing the nasopharynx to such an extent that it would interfere with breathing or swallowing yet, as Rosenthal emphasizes the flap should not be made too narrow Moran points out that the pharyngeal flap operation should be restricted to those secondary palate cases where operative correction has not brought about

(Fig 159) A tongue-shaped flap is outlined at the posterior wall of the pharynx, its free edge is placed as high (cranially) as possible, the pedicle comes to lie downward. It should be at least 2 cm ($1\frac{3}{16}$ inch) wide The orifices of the Eustachian tubes should be looked for and avoided To outline such a flap, the arches of the soft palate must be retracted anteriorly Traction sutures are placed at the lateral margins of the flap, and incisions are made through the mucosa and superior constrictor

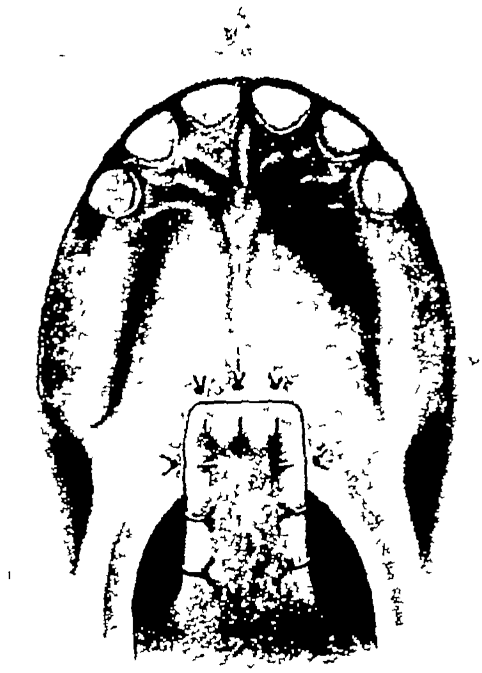


Fig 161 The posterior pharyngeal flap (based inferiorly) is sutured to the raw area on the oral aspect of the soft palate (H Conway Plast & Reconstruct. Surg)

pharyngeus muscle. The flap is dissected away from the prevertebral fascia and the donor area at the postpharyngeal wall closed with catgut sutures Rosenthal emphasizes the importance of this step, since it helps bring about a "mesopharyngoconstrictio" for improvement of phonation A mucosal flap is now made from the oral surface of the soft palate (Fig 160) This flap is hinged posteriorly. The mucosal defect of the pharyngeal flap bed is closed by suturing the wound edges together The pharyngeal flap is now laid upon the raw surface of the palate and of the hinge flap and sutured to the wound edges (Fig 161)

Technic (Velopharyngorraphy after Trauner): In this method, part of the posterior rim of the soft palate is united with the posterior pharyngeal wall so that only two small lateral openings and one median are left to permit nasal breathing and passage of nasal secretion From an incision along the posterior rim of the soft palate, starting near the tonsillar fossa and crossing the uvula, the velum is split in three layers, as in preparation

Fig. 159 Conway's technic of transfer of postpharyngeal flap to soft palate. First step in the construction of a posterior pharyngeal flap. The rigid soft palate is retracted forcibly so that the flap will have sufficient length to bridge the gap of the wide open velo-pharyngeal aperture. In a typical procedure the flap is 2 cm. wide and 6 cm. long. If the flap is not fashioned from a high enough level, attempts to mobilize a shorter flap by caudal extensions of the two parallel incisions may cause undue tension on the flap when sutured to the soft palate. Mucosa and superior constrictor pharyngeus muscle are included in the flap. The posterior pharyngeal defect is closed by undercutting and suture of the cut margins of muscle and flap so that the sphincteric action of the constrictor muscle is regained. (H Conway Plast. & Reconstruct. Surg.)

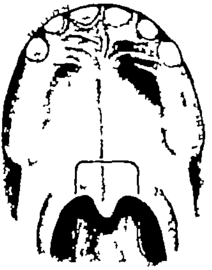


Fig. 160: The lines on the soft palate indicate the incision for attachment of the soft palate The mucosa thus outlined is rotated posteriorly so that a rectangular raw surface presents on the oral side of the soft palate to which the pharyngeal flap is sutured. (H Conway Plast. & Reconstruct. Surg.)

incision, the inner wound edges are turned inward (a similar procedure is depicted in Figs 146, 147), and the defect is covered with a single, posteriorly pedicled flap, which is taken from the immediate neighborhood of the defect The secondary defect, resulting from shifting the flap, is left to granulate. In defects with *extensive loss of tissue,* in either the hard or soft palate or both, flaps from the palate itself are not available Hence, one must resort to the transfer of buccal mucous-membrane flaps or, if the soft palate is defective, pharyngeal flaps Occasionally, lined flaps from distant parts of the body are required, such as from the hairless region of the upper arm or neck and chest Edgerton and Zovikian and others have demonstrated remarkable successes In patients with large anterior holes and short and even partially cleft soft palates, Struppler performs closure of the cleft with such a flap and a velopharyngorraphy after Trauner He prepares the flap for closure of the hole in the same sitting (velopharyngorraphy), while closure of the hole with the flap is performed in subsequent sittings

SPEECH—TRAINING AND ORTHODONTIA

Cleft-palate repair has two aims anatomical restoration and development of normal speech If the repair has resulted in a well-arched palate and sufficient velopharyngeal closure, the young patient as a rule is able to develop normal speech In certain other patients, however, even after good surgical closure, a speech defect may be left, owing to shortness of the palate, dental malocclusion, psychological handicaps, and the like. Speech-training alone is often not enough, and additional surgery may be required (see p 268-278), as well as an effective rehabilitation program These patients should have the benefit of opinions from various specialists, such as the surgeon, orthodontist, otolaryngologist, psychologist, and speech therapist. Recognition of this fact is leading to the establishment, in various parts of this country, of group clinics, which are financed either privately or publicly, for the rehabilitation of cleft-palate patients

Deformities

MICROSTOMA

Technic for Cicatricial Microstoma (Dieffenbach; Modified after Lexer) (Fig 162) A triangular-shaped piece of skin and muscle is removed lateral to each side of the microstoma, leaving the mucous membrane intact. The tip of the triangle should come to lie on a level perpendicular with the pupilla The vermilion border, together with the mucous membrane, is now cut across to a point close to the tip of the tri-

for closure of clefts of the soft palate The palate is now pressed against the posterior pharyngeal wall A curved incision is made through the latter in line with the posterior palate rim. The incision goes through the mucosa and muscle layer The lower part of the pharyngeal wound is mobilized and elevated a short distance. If possible the posterior or nasal mucosa of the soft palate is sutured to the upper pharyngeal wound edge The main suture however is a mattress suture of nylon through the muscles of the velum and pharynx two such sutures are placed one on the right and one on the left side. A long, curved needle enters the oral mucosa of the velum about 1.5 cm (9/16 inch) from the wound edge in front of the tonsillar fossa penetrates the muscle layer and escapes near the wound edge of the nasal mucosa The other end of the thread is laid more mediad and about 1 cm (3/8 inch) from the wound edge in a similar way Both ends are now passed behind the muscle layer of the lower pharyngeal wound flap to escape through the pharyngeal mucosa through different exits which should be about 1.5 cm. (9/16 inch) from the wound edge. They are now tied over small short rubber tubings Suture of the oral palatal and lower pharyngeal wound edge follows Trauner originally left a 5-mm (1/4 inch) hole in the middle but re cently has not done so If the lateral openings are not sufficient to permit sufficient drainage of nasal secretion it is easy to create an opening in the center with a pair of scissors The nylon sutures are removed on the tenth postoperative day

Trauner and those who have had experience with this method claim greater improvement of speech following it than with any other If the palate is too short, a pushback operation (after J B Brown) may be performed in the same or a preceding sitting

SECONDARY REPAIR OF PALATINE DEFECTS

Smaller or larger holes or defects of the palate following primary repair can be successfully closed surgically in the majority of cases It is the consensus that obturators, fastened to the dental arch should be recommended only in exceptional cases since most patients grow dis satisfied with these appliances It goes beyond the scope of this book to describe in detail all the various methods which have been recommended for repair Size and location of the defect vary consequently surgical methods differ and have to be adapted to each case. Padgett in an excel lent article evaluates many of the applicable procedures

Small fistulas usually located at the junction of soft and hard palate may be successfully closed by frequent touching of the area with tincture of cantharides or silver nitrate *Larger holes* are circumscribed by an

The correction of the ectropion consists in excision of the entire contracting scar, reduction and overcorrection of the contracture, and application of a thick split graft The sutures of the graft are left long and tied over mechanic's waste to exert pressure In those cases, however, in which much of the subcutaneous tissue is destroyed and replaced by scar tissue, a flap should be transplanted after removal of all cicatricial tissue

a *b*

Fig 163, *a* Repair of cicatricial displacement of angle of mouth by formation of two triangular flaps Their outlines form an N *b* Two triangular flaps are exchanged with each other

CICATRICIAL ENTROPION AND RECONSTRUCTION OF OBLITERATED GINGIVOLABIAL SULCUS

The entropion of the lip is due to scar formation at the mucous-membrane side and, as a rule, is combined with cicatricial obliteration of the gingivolabial sulcus The repair of the latter corrects the deformity of the lip The reconstruction of the gingivolabial sulcus is done according to the Esser-Waldron technic (see p 37) With an incision along the obliterated sulcus, the lip is freed from the bone deeper than required so that secondary shrinkage may be counteracted A mold of dental compound is now prepared, as described on p 37, and a skin graft draped around it with the raw surface outward, after insertion of mold and graft, the margins of the wound are sutured, thus burying the mold If the margins of the wound cannot be sutured, the mold must be held in place by other means. In the case of a lower lip, this is done with two circumferential wires placed between two teeth around the mandible, as described on p 421 Mold and graft are inserted into the gutter between the wire loops and the wires tightened around them. In the case of an upper lip, sutures are placed around the mold through the upper parts of the lip and tightened at the outside over small rolls of gauze. For postoperative treatment, see p 37

angular defect leaving a mucous-membrane angle which should now be sutured to the tip of the triangular skin defect. This may be facilitated by blunt separation and mobilization of the adjacent mucous membrane of the cheek. The mucous-membrane flaps are now united with the skin edges There may be some buckling where the vermilion border passes

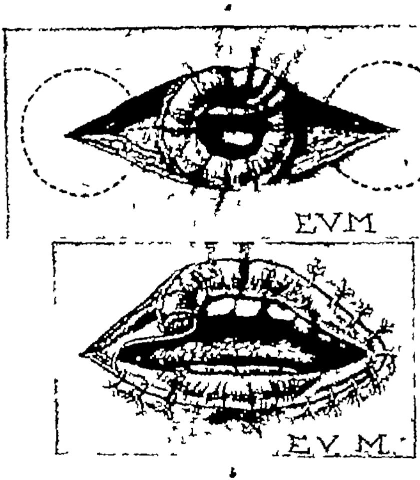


Fig. 162 a Repair of cicatricial microstoma (Dieffenbach-Lexer) Removal of triangular pieces of skin. Dotted lines indicate extent to which surrounding skin is undermined. b Vermilion border and mucous membrane are cut across and sutured to wound edges.

over into the mucous membrane Removal of a rhomboid piece of the vermilion border edge will correct the deformity

Technic (May) In microstoma following the switching of vermilion border lined flaps, a double Z-operation is applicable, as described on p 195

CICATRICIAL ECTROPION OF LIPS

These deformities are in the majority of cases due to burns In cases of the lower lip the contracture may involve the lip alone or may be due to pull from scars involving chin and neck (Cases 2 19 77 pp 846 872 916)

SECONDARY DEFORMITIES AFTER REPAIR OF CLEFT LIP

For repair, see p 247

DEFORMITIES OF CHIN

For reparative surgery of deformities of the chin, see p 438–449

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CICATRICIAL DISPLACEMENT OF ANGLE OF MOUTH

This condition is corrected with the "N" type of incision The operation starts with a V like incision circumscribing the angle of the mouth (Fig 163) The incision penetrates through the whole thickness of the cheek In the case of an upward displacement an incision is made through the cheek starting from the lower end of the V and running parallel to its upper arm Thus two triangular flaps are created, which are exchanged with each other in a manner similar to that in the Z-operation (see p 147) Downward displacements can be repaired by a reversal of the procedure

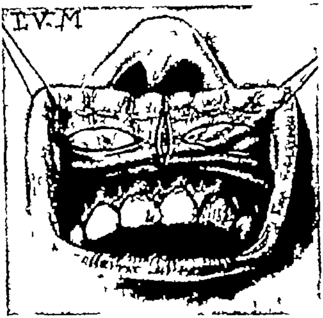

Fig. 164 Correction of double lip. Horizontal excision of elliptiform piece of buccal tissue from each side of lip. Excision of vertical piece to avoid buckling of midportion.

HYPERTROPHY OF LIP AND DOUBLE LIP

Simple hypertrophy of the lip becomes particularly noticeable if associated with a hanging lip The operation for repair of the deformity is simple. With an elliptiform incision reaching from commissure to commissure along the mucous membrane on the posterior side of the lip a wedge-shaped piece of tissue is removed of proper thickness and the defect closed by simple suturing To avoid buckling of the midportion of the lip additional excision of a vertical wedge-shaped piece of tissue may become necessary as it is done for correction of a double lip (Fig 164) The latter usually the upper lip is due to a groove bisecting the vermilion border Concerning repair of this deformity Fig. 164 is self explanatory

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IX

THE NOSE AND INTRANASAL REGIONS

ANATOMY The external part of the nose is pyramidal Its root, located below the glabella, forms with the latter the frontonasal angle From here, the dorsum, or the ridge, of the nose descends downward, ending at the tip The base of the nasal pyramid is represented by the two nostrils. The lateral walls connect the dorsum with the cheeks (Fig. 165) A detailed description of the anatomy of the nose, particularly with reference to plastic surgery has been presented by Converse and by Straasma

The various parts forming the external nose can be divided into framework, covering, and lining. The framework is osseous in its upper half, it is cartilaginous in the lower half The *osseous framework* consists of the two nasal bones which rest upon the frontal processes of the maxilla At the root of the nose, they articulate with the frontal bone and the perpendicular plate of the ethmoid bone The *cartilaginous framework* consists of the lateral cartilages and the cartilaginous part of the septum The upper lateral cartilages (cartilagines nasi laterales) are triangular and join the septal cartilage, in the midline. The caudal two thirds are separated from the cartilaginous septum by a narrow connective-tissue cleft, while the cephalic third is continuous with the cartilaginous septum (Straatsma and Straatsma) The lower lateral cartilages (alar cartilages—cartilagines alares) consist of two parts a crus laterale, which forms and determines the shape of the ala and nostrils, and a crus mediale, which, with its fellow from the other side, forms the tip of the nose and the mobile part of the septum called the "columella" These alar cartilages are semimobile, since they are attached only loosely to the upper lateral cartilages and the septum They shape the nasal tip and,

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is supplied by the nervus olfactorius, the nervus nasopalatinus, and the nervus ethmoidalis anterior

For esthetic considerations and preoperative planning, see p 308

Defects

Defects of the nose are quite often composite, requiring the replacement of the missing tissue by similar tissue. The defects may involve only parts of the nose or the entire nose; they may involve the soft tissue or the framework or both

DEFECTS OF SKIN OF NOSE

Defects of the nasal skin are more often due to removal of tumors than to injuries. These defects are replaced by either skin grafts or flaps depending upon the depth of the defect If sufficient soft tissue (sub cutaneous tissue, periosteum, perichondrium) is left behind, transplanta tion of a free skin graft is the best choice. The full-thickness graft taken from behind the ear (compare with Fig 203) or from the supraclavicular region is preferred, since it best matches the facial skin In small defects of skin and cartilage, MacFee uses a composite graft of skin and cartilage from the posterior surface of the ear for closure The auricular donor area is covered with a split skin graft The author recommends taking the graft from the anterior surface of the concha, since skin and cartilage are more firmly attached (see Fig 172) (For other types of grafts, see p 300)

Dupertuis, who was preceded by Zeno, reports successful use of free earlobe grafts of skin in closure of skin defects about the nostril and the tip of the nose He takes the grafts from the straight portion of the lobe between the tail of the helix and the dependent curve A triangular, wedge-shaped piece of lobe is excised and the resultant defect then closed by laminated approximation of the cut edges Although he was able to transplant such a graft successfully in correcting full-thickness defects about the nostril and the tip of the nose, he also demonstrated good results from splitting the earlobe graft to accept the cartilaginous edges if the alar cartilage was intact

If bone and cartilage are exposed or missing, transplantation of a flap becomes necessary (Case 38, p 898, for source of flap, see p 300)

DEFECTS OF COLUMELLA

The technic of replacing the columella alone differs from that used in replacement of subtotal or total defects of the nose For technic of the latter, see Figs 173–175

through their continuation into the columella determine the height of the nose Sometimes there are additional smaller cartilages

The *nasal septum* is the partition of the nasal fossa and consists of the crus mediale of the lower lateral cartilages (columella), the cutaneous septum (skin connection between columella and edge of septal cartilage) the septal cartilage the perpendicular plate of the ethmoid and the vomer The septal cartilage is the most important part of the nasal

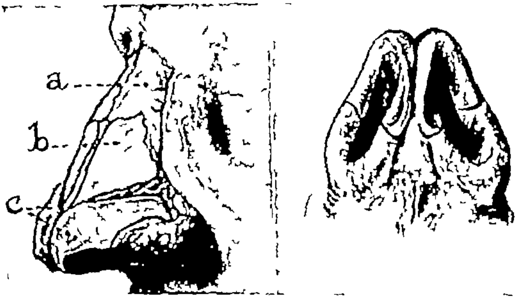


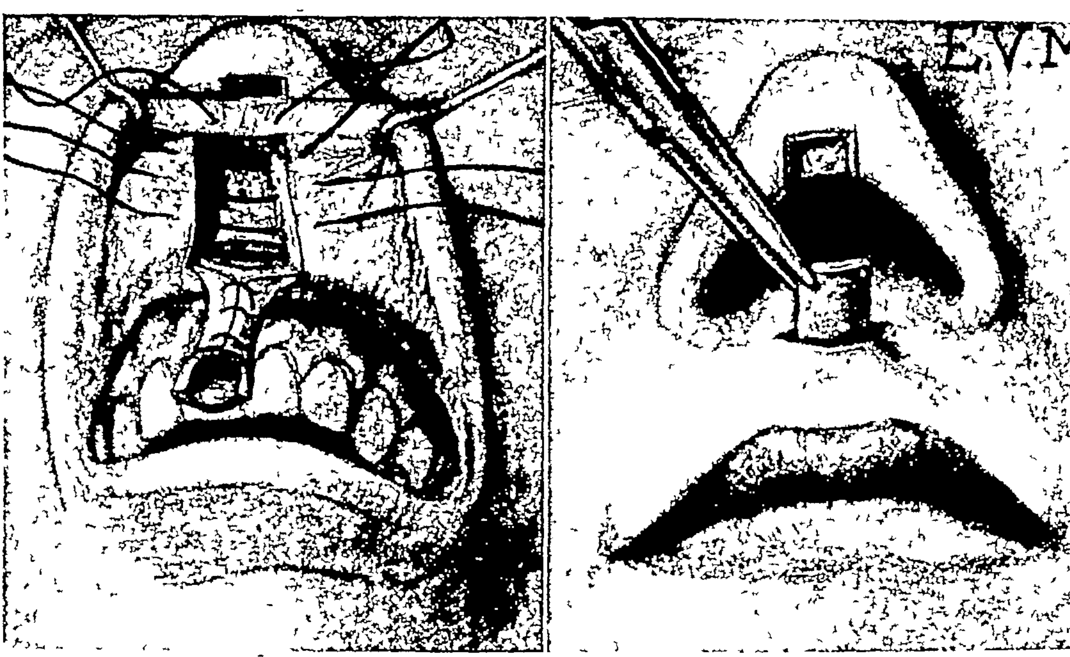
Fig. 165: Anatomy of nose.

septum It is flexible and if distorted, bent, twisted deviated, or dislocated from its base at the nasal spine or the vomer it may displace the surrounding structures.

The *skin* covering the upper part of the nose is thin and freely movable while the skin covering the alae and tip is thick and firmly attached to the subcutaneous structures The *nasal muscles* are *insignificant* they belong to the facial muscles, and have some influence in enlarging and narrowing the nares.

The *arteries* are the arteria dorsalis nasi a terminal branch of the arteria ophthalmica and branches of the arteria maxillaris externa The terminal branch of the latter the arteria angularis, anastomoses with the former The *veins* empty into the vena facialis anterior there are also connections with the vena ophthalmica superior The following *sensory nerves* supply the external nose the nervus ethmoidalis anterior the nasal tip and alae the nervus infraorbitalis the dorsum and lateral parts the nervus infratrochlearis the skin of the root The nasal cavity

forehead flap (see p 298, Case 38, p 898) or a flap from the side of the nose, pedicled over the nasomaxillary angle and extending obliquely downward along the nasolabial fold, is used. In still deeper and extensive defects, particularly those involving parts of the alae and columella, a tube flap, preferably from the lateral cervical region or in women from the upper-neck region across its anterior surface or from the upper arm, should be transplanted After the flap is severed and sufficient time has elapsed to allow for shrinkage, the tubed part of the flap is opened and adjusted in such a way as to form the upper rim of the nostrils and to replace the uppermost part of the columella (Case 39, p 900)



a *b*

Fig 166, *a* Replacing columella (after Lexer) A mucous-membrane flap, pedicled in the gingivobuccal fold of the upper lip, is tubed *b* Flap is transferred through slit of upper lip to be sutured to nasal tip

DEFECTS OF ALA

Defects of the ala may comprise parts of the ala, the entire ala, or ala and parts of the nasal tip It is fully realized that—as far as the various reparative methods are concerned—a division as outlined in the previous sentence is insufficient, since a full-thickness defect, for instance, may be surrounded by cicatricial tissue instead of normal skin The removal of the scar tissue inevitably increases the size of the defect and, furthermore, forces a change in the reparative plan if the use of some of the surrounding skin is to be used as a lining Nevertheless, only concrete examples can be quoted, leaving variations to the ingenuity of the operator In the majority of instances, replacement of the covering and lining

Technic (Lexer) (Fig 166) A mucous-membrane flap about 1.5 cm (5/8 inch) long and pedicled in the gingivobuccal fold is tubed and transferred through a slit of the upper lip The site of the lip perforation is above and close to the base of the pedicle. The peripheral end of the flap is adjusted to conform with the shape of the columellar defect at the nasal tip and sutured into the latter The secondary defect in the upper lip is either closed or left open The red color of the mucous-membrane flap becomes paler and less noticeable after a few weeks

Technic (Smith) A double-pedicle flap is formed from the same region as in Lexer's method The posterior raw surface of the flap is covered with a skin graft. After two weeks the proximal (superior) pedicle is severed, and the lip is everted and fixed in this position to the cheek with silver wires passed through a lead plate and held with adhesive tape. The flap is turned over and the peripheral end is now sutured into the defect at the nasal tip After three weeks the base of the flap is severed from the lip and sutured into the skin of the lip at the point of the columellar attachment

To lengthen a congenitally short columella Pegram divided the columella at the base advanced it anteriorly and filled the resulting defect with a composite graft taken from the base of one ala Apparently closure of the latter defect did not result in asymmetry

Technic (Savanero-Roselli) The philtrum is elevated as a bridge flap the undersurface is covered with a split skin graft. After the graft has healed in place the peripheral pedicle of the flap near the vermilion border is severed the flap is hinged upward and sutured to the tip of the nose. The area at the donor site is closed by skin-sliding

Lexer and Smith's technics have not found many followers The philtrum flap of Savanero-Roselli has only limited use i e in patients with long upper lips in whom the columella is short

Savanero-Roselli offers another method whereby a lined pedicle flap pedicled near the nostril is transferred from the cheek Schuchardt mobilized the flap not from the cheek but from an area lateral to the nose the flap is made narrow and thick and transferred and sutured to the nasal tip after the graft has healed in place the resulting scar from closure of the donor area is satisfactory since it lies along the base of the nose four weeks after transfer of the flap it is severed from its pedicle near the nostril and flap and pedicle are adjusted in place.

DEFECTS OF TIP OF NOSE

Transplantation of a free skin graft can be successful only in superficial defects which do not involve the framework. In deeper defects a

Small and Medium-Sized Defects Near Base of Ala

The lining of these defects is provided by hinging a flap from the nasolabial region, the covering is provided by a skin graft.

Technic (F. Smith) (Fig 168) *Stage 1* A flap of sufficient size, with its pedicle near the base of the ala, is outlined in the adjacent naso-

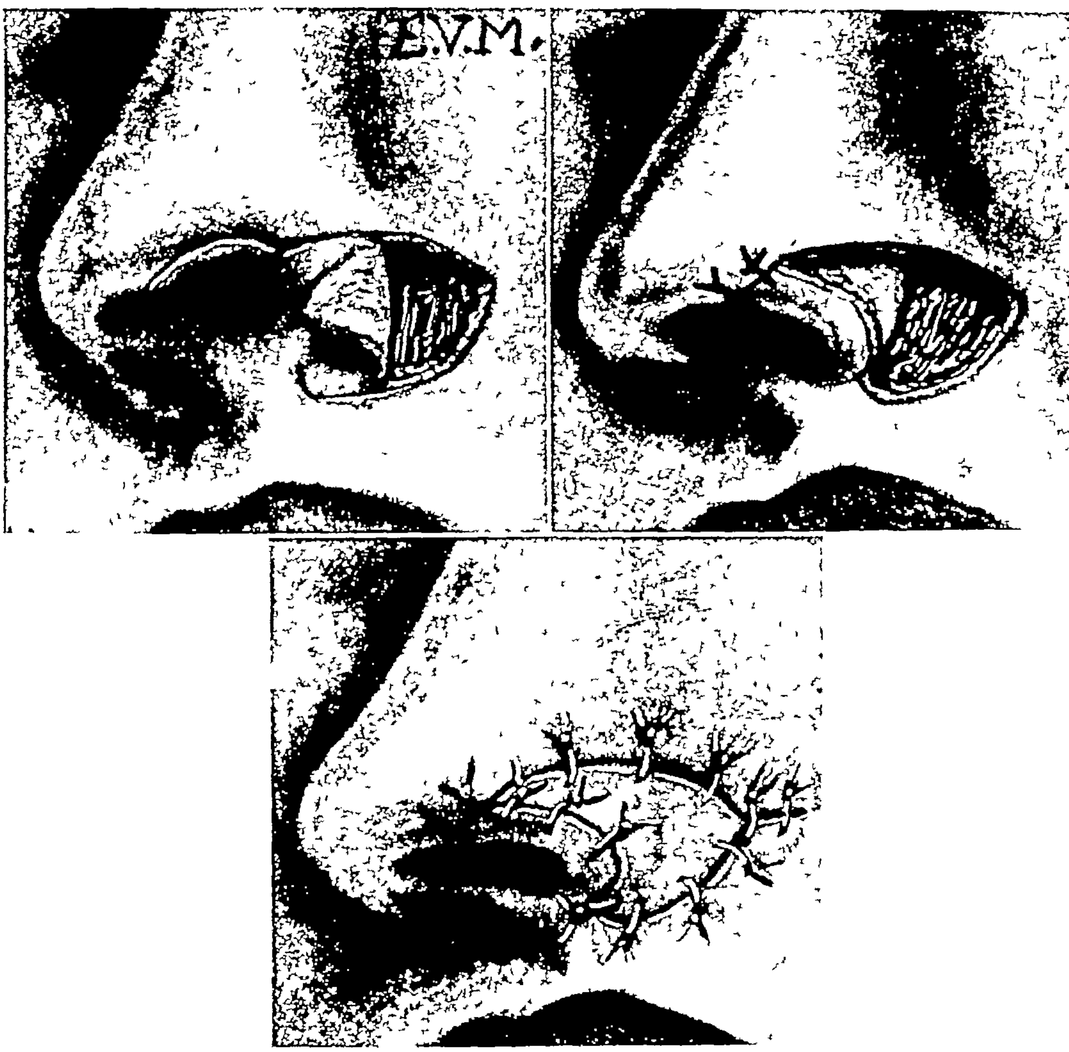


Fig 168 Repair of smaller and medium-sized defects near base of ala Lining is provided by hingeing flap from nasolabial region Inferior part of flap should be made so broad that after flap is hinged it can be turned over to form rim of nostril Covering is provided by skin graft. (F Smith Manual of Standard Practice of Plastic and Maxillofacial Surgery W B Saunders Co)

labial region. The inferior part of the flap should be made so broad that after the flap is hinged, it can be turned over to form the rim of the nostril. The flap is raised and returned to its original site

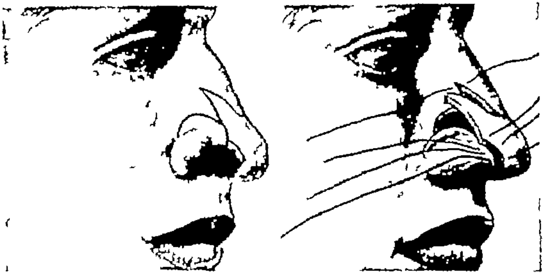
Stage 2: After two weeks, the flap is again raised and transplanted, but if the blood supply is still insufficient, the flap should be returned

is sufficient. In some instances however a thin cartilage graft (ear cartilage) is required for support.

Small Defects of Ala Near Nasal Tip

Technic (Denouvilliers-Joseph) (Fig 167) A flap is formed consisting of the whole thickness of the entire remainder of the ala. The flap pedicled at the base of the ala, is rotated downward and its peripheral end sutured to the lateral border of the nasal tip The secondary defect above the ala is covered with a flap from the lateral wall of the nose This flap also consists of the full thickness of the nasal wall The donor area from which this flap was taken is closed by simple suturing

Another method is the free transplantation of a composite graft from the helix of the ears (see Fig 170 Case 37 p 897)



a b

Fig. 167 a. Repair of small defect of ala near nasal tip (Denouvilliers-Joseph) A triangular full-thickness flap of entire remainder of ala is formed and a similarly shaped flap of lateral wall of nose. b: Alar flap is moved downward and sutured to prepared place at tip of nose. Flap of lateral wall of nose is rotated into defect above ala. Defect at lateral wall of nose is closed by simple suturing.

Medium-Sized Defects of Ala Near Nasal Tip

These defects are best closed by hinging a skin flap from above the defect downward to provide the lining· the entire raw surface is covered with a full thickness graft from the posterior surface of the ear The hinge flap should be sufficiently long to permit the peripheral part—after the flap has been turned downward—to be turned over to form the rim of the nostril (F Smith) (compare with Fig 69)

Another method is the free transplantation of a composite graft from the helix of the ear (see Fig 170 Case 37 p. 897)

encountered. Careful hemostasis, rather by pressure than by ligation, is next applied A pattern of the defect is made, and a section of the helix of the ear corresponding in size and shape is removed (Fig 170) The posterior skin of the graft is carefully sutured to the mucous-membrane

a

b c

Fig 169, *a* Repair of defects of rim of ala (Kazanjian) A curved incision is made above margin of defect through skin and cartilage only (V H Kazanjian Tr Am Acad Ophth)

b Mucous membrane is carefully separated from skin to extent outlined by dotted lines Mucous membrane is severed along upper dotted line and moved downward Defect from which mucous membrane has been shifted (shaded area) is left to granulate

c, Defect above alar rim is skin-grafted

for another two weeks The defect s edges are split and the flap sutured to the mucous-membrane lining with the sutures tied intranasally The inferior border of the flap is rolled outward to form the rim of the nostril The donor area in the nasolabial region is closed by skin-sliding after mobilization of the borders of the wound unless the area is too large and consequently requiring transplantation of a skin graft from the posterior surface of the ear The raw area of the hinged flap is covered with the same full thickness graft or with a full thickness graft from the posterior surface of the other ear The repaired side of the nose is packed with plain gauze and a pressure dressing is applied to the outside This is left in place for ten days

Variation Another method is the free transplantation of a composite graft from the helix of the ear (see Fig 170 Case 37 p 897) or from the base of the sound nostril (Davis)

Defects of Rim of Ala

Technic (Kazanjian) (Fig 169) The borders of the defect are utilized to form the alar rim A curved incision is made a few millimeters behind the margin of the defect through the skin and cartilage only the mucous membrane is carefully separated from the overlying skin and cartilage and part of the nasal bone A mucous-membrane flap is now cut as indicated by the shaded area of Fig 169 *b*, the mucous-membrane flap is brought down together with the alar rim the defect at the inside of the nose above the mucous-membrane flap is left to granulate and the skin defect above the alar rim is covered with a full thickness graft from the posterior surface of the ear The nose is packed with plain gauze and a proper pressure dressing is applied upon the graft

Another method is the free transplantation of a composite graft from the helix of the ear (see Fig 170 Case 37 p 897)

Defects of Entire Ala

For repair of defects of the entire ala the following are available free transplantation of a composite graft from the helix of the ear, flaps from the immediate neighborhood and flaps from distant parts.

Composite grafts from the helix of the ear have been successfully used by Susloff and Fritz Koenig J B Brown revived the method and demonstrated its extraordinary success at Valley Forge General Hospital in many cases

Technic (Fig 170) Healthy wound edges of the defect are imperative for success They are the only source from which the graft receives its blood supply The defect s edges are excised until normal healthy tissue is

ten days, the flap is transferred and the donor area is closed by skin-sliding This may cause a pull on the upper lip, but the tension is usually only temporary

In defects that are not too broad, a flap adjacent to the nose within the nasomaxillary area can be utilized The pedicle is placed adjacent to the nostril

a b

Fig 171, *a* Repair of defect of entire ala with flap which is rotated from adjacent cheek (Dieffenbach) Pedicle of flap is placed so that after rotation it forms base of ala Flap may need to be raised in stages if circulation is inadequate It is lined with a thick split graft and returned to its original site *b* Ten days after flap has been lined, it is rotated into the defect, and the secondary defect at cheek is closed by skin-sliding

EXTENSIVE DEFECTS OF ALA

For extensive defects, particularly those which include portions of the tip and lateral wall of the nose, flaps from distant parts must be chosen Suffice it to say that these flaps should be lined (by folding the peripheral end of the flap upon itself, for instance) A lateral (or, in women, a transverse) cervical tube flap from the upper anterior neck region or the acromiopectoral, arm, forehead, sickle flap, or an improved forehead flap (New) (Fig 172) is available Whenever possible, a forehead flap should be used

Gillies' suggestion of lining the flap with a piece of skin plus cartilage taken from the concha of the ear seems to be excellent (Case 41, p 902, Fig 172) Kazanjian advises the median forehead flap (Case 38, p 898). Two parallel incisions are made over the forehead from 1 2 to 2 5 cm. (½ to 1 inch) apart, extending from the hairline to just above the frontal eminence on both sides The flap is raised, and when it reaches the eyebrows, blunt dissection is carried downward almost to the root of the

edge of the defect with finest silk sutures on an atraumatic needle the anterior skin to the skin edge The defect at the ear is closed either by making the ear slightly smaller (Fig 239) or in larger defects (Case 37 p 897) by suturing the ear to a flap at the hairless mastoid region (After three weeks this flap is severed its free end is hinged posteriorly [Case 66 p 934]) The graft at the nose must be carefully supported by packing the nostril and by the application of moderate pressure from outside

Fig. 170: Defect of entire ala repaired by free transplantation of composite graft from helix of ear (F König) Defect at ear is immediately repaired with flap raised from hairless postauricular region. This flap is severed after three weeks and its posterior raw surface skin-grafted.

Lexer's advice is recommended in the preparation of the donor area To increase the contact surface of graft and host area, the incision along the rim of the defect is curved so that a small skin flap can be turned downward and inward this increases the wound surface. The skin surface of the graft which comes to lie inward must of course be made correspondingly small

Technic (Dieffenbach) (Fig 171) If the skin of the cheek adjacent to the defect is healthy rotation of a flap from the immediate neighborhood is possible The flap is mobilized from the nasolabial region The pedicle is placed so that after rotation of the flap it forms the base of the ala Fig 171 is self-explanatory The flap should be made wide enough to allow for shrinkage It is elevated and lined with a split skin graft returned to the donor area and covered with a pressure dressing After

nose thus saving the frontal vessels from injury The donor area is closed by wide undermining and by making one or two incisions under the undermined skin parallel to the incised edges through the fascia but without penetrating all of the subcutaneous fat or any of the skin This procedure of relaxation incisions through the fascia will allow approximation of the borders of the wound without undue tension Larger defects are closed by advancing two forehead flaps from each side of the defect. The incisions for formation of these flaps are made just above the eyebrows for the lower borders and just within the hairline for the upper borders.

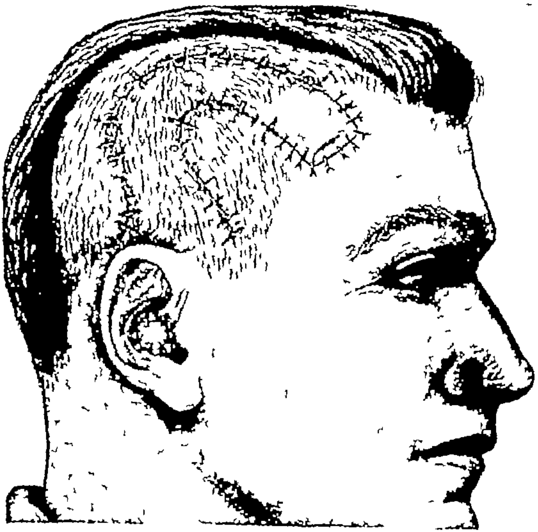


Fig. 172: Replacement of entire ala by so-called "sickle" flap (after New) and lining of flap with piece of skin plus cartilage taken from concha of ear (after Gillies) Sickle flap has been raised in stages In first stage, it is raised between temporal and forehead pedicle. In second stage four weeks later forehead pedicle is severed, and entire flap is raised and returned to its original site. In third stage, after all edema has subsided, peripheral part, or forehead part, of flap is raised and lined with piece of skin plus cartilage taken from concha of ear This part is again returned to its original site and defect in concha is skin-grafted. Flap is ready for transfer one week after lining. (For more extensive defects, see Case 41 p 902.)

must be lined (see pp 87–88) unless local flaps can be turned over A preoperative step similar to that shown in Fig 69 *a* (2) should be performed before the flap is turned over as a means of enhancing its circulation If support is needed a cartilage or bone graft is inserted between skin and lining after the flap has healed in

SUBTOTAL AND TOTAL DEFECTS OF NOSE

Subtotal defects of the nose comprise defects of either the cartilaginous or the bony part of the nose In total defects covering skin lining and entire framework are absent. The methods developed for replacing such large nasal defects are numerous Although some of the older principles still govern modern technic, many details have been changed and improved The forehead flap based on the principles of the old Indian method is best for matching color and texture. Its use may not be advisable owing to a low hairline or objection from the patient to scar formation The next choice then is the arm flap or an acromiopectoral flap

Forehead Flap

In constructing a new nose the following requirements are necessary replacement of the covering lining and supporting tissue sufficient breathing space and last but not least a pleasing cosmetic result The formation of the columella alae nostrils, and their lining is achieved by folding the peripheral end of the flap over as—according to Dubowitzky—first practiced by Labat (1830) and somewhat later described by Petrali Besides the advantages mentioned this method almost guarantees maintenance of the prominence of the nasal tip without additional cartilaginous or bony support The disadvantage is that the nostrils are more or less obstructed by bulky skin and subcutaneous tissue requiring secondary correction The lining of the upper half of the nose is provided by turning over local flaps or by lining the forehead flap with a full thickness graft. Support of the ridge of the nose is provided by transplantation of a cartilaginous graft Ivy advises inserting the cartilage as a finishing touch rather than to place it beneath the flap on the forehead before it is brought down since it is much easier in the former case to judge the proper size shape and position to be given to the cartilage Lexer and others advise insertion of bone grafts beneath the forehead flap before it is transferred This method provides ample breathing space but the shape of the nose may leave much to be desired

The total restoration of a nose resulting in a pleasing shape in thin alar rims and in nostrils that will stay open is difficult It must be carefully planned and well executed

Step 6 After two weeks, the pedicle of the flap is partly severed, this is done in V-fashion, following the technic of Penn (Fig 178-*b*) The separation is completed at the end of the third week The pedicle is returned to its original site and the flap adjusted in place

Step 7: If the ridge of the new nose needs support, a properly shaped and sized piece of cartilage is inserted, after the wound healing is completed. An incision is made below the glabella, a pocket is made between skin and lining, and the cartilage graft is inserted into this pocket

If nasal ridge and columella need support, a hinge graft is inserted according to the technic described on p 330 Other secondary corrective work may be needed to correct scars, to form the nostrils (see Fig 176), and the like

Variation: If the case is such that the lining of the nose cannot be replaced by local turnover flaps, the forehead flap must be lined prior to its transfer (Figs 173, 174) About two weeks before the final transfer, the peripheral end of the flap is raised, and a full-thickness graft is sutured to that part of the flap which needs to be lined

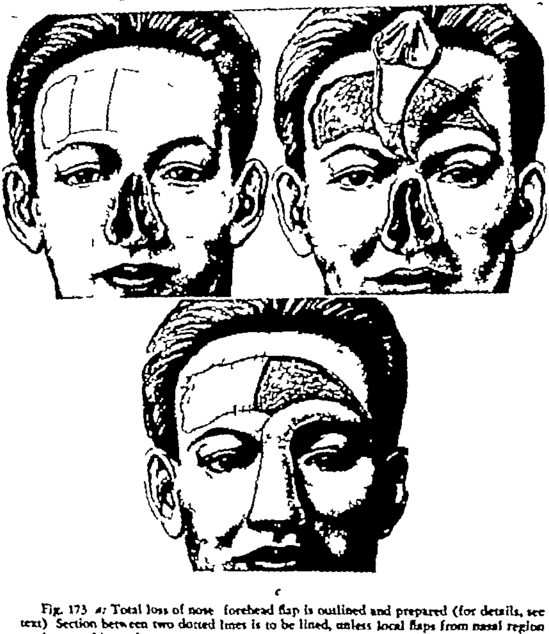
The forehead flap described in the foregoing is the oblique type For obvious reasons, it leaves scars across the forehead To hide most of these scars, it may be possible to utilize the principle of the sickle flap (see p 300) The peripheral end of the flap is placed either mediad (Case 42, p 904) or laterally (Figs 174–176), depending upon the width of the forehead Such a flap must be raised in stages Other flaps constructed on the same principle may be transplanted in one stage, i e, the "scalping" forehead flap of Converse (Fig 177) and the "horseshoe" flap, modified after Penn, may be of great help (Fig 178) Since they are based on the supraorbital vessels, they have an excellent blood supply and need not be delayed unless lining of the flap is required The peripheral end (forehead skin exclusive of scalp) of these three types of flaps, however, is as a rule not of sufficient length to permit reconstruction of the whole nose

Lexer and others insert bone grafts beneath the forehead flap before it is transplanted The author has had personal experience with his former teacher's method, he agrees with others that his technic of total rhinoplasty results in an ample breathing space—if the bone grafts are made sufficiently broad—but the shape of the nose may leave much to be desired

Technic (Lexer). A forehead flap is prepared similar to the one of 173*a*, and described in the technic of p 302 The end of the flap is 8 to 9 cm ($3\frac{3}{16}$ to $3\frac{5}{8}$ inches) broad and has an extension for the columella Two thin but broad bone grafts 4 cm ($1\frac{5}{8}$ inches) long, are taken from the anterior surface of the tibia and placed side by side

wound edges of the defect. The forehead defect corresponding to the nose pattern is covered with a full thickness graft which is cut according to the tinfoil pattern. A proper pressure dressing is applied to the forehead. The nose is loosely packed with plain gauze and covered with a dressing.

a b



c

Fig. 173 a: Total loss of nose forehead flap is outlined and prepared (for details, see text). Section between two dotted lines is to be lined, unless local flaps from nasal region can be turned inward.

b: Flap is mobilized lower end is folded in such fashion as to provide lining for lower portion of nose and columella.

c: Flap is transplanted; secondary defect at forehead is covered with full-thickness skin graft.

flap is prepared as an open double-pedicle flap, undermined between two longitudinal parallel incisions It remains attached with a proximal and distal pedicle (see p 302), and is returned to its original site The proximal or distal pedicle—the choice is dictated by circumstances, and must be predetermined according to pattern—is severed after two weeks, and after hemostasis is sutured in place Two weeks later, the entire flap is raised and returned to its original site After all edema in the flap has subsided (from two to four weeks), the flap is ready for transfer The flap is raised, the flap bed skin-grafted, and the peripheral part of the flap

Fig 175, *a* The flap (Fig 174) is raised and its lower end is folded to form columella, ala, nostrils and their lining

Fig 175, *b* Folded skin is held in place with mattress sutures Uppermost mattress suture above alae should go through both sides to form normal "pinch" above alae Flap is sutured in place

sutured to the glabella and the lateral edges of the defect (Fig 179) The arm is held in this position with a plaster cast After two weeks, the flap is gradually severed from its base Enough tissue should be left at the flap to allow folding of the lower end of the flap to provide lining of the lower portion of the nose and the columella (see Figs 173, 175) The flap should be folded, however, only after all edema in the flap has subsided.

beneath the main part of the flap to furnish the lateral walls and framework of the nose. After four weeks or longer the entire composite flap is elevated and lined with a skin graft. After two weeks the flap is elevated and folded for formation of the root of the nose and transplanted care being taken that the bone grafts come in intimate contact with the maxillary bone The flap is severed after from six to eight weeks not earlier to guarantee sufficient vascularization of the bone grafts Secondary operations are necessary to shape the nose nostrils columella and the like

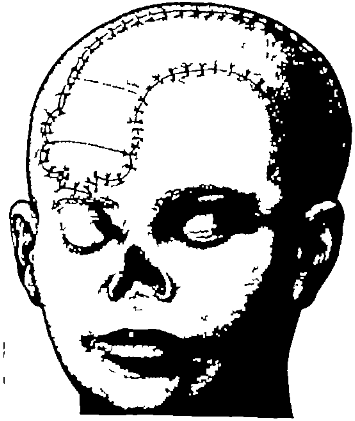


Fig. 174: Subtotal loss of nose sickle flap with laterally placed peripheral end is outlined and raised in stages. Section between dotted lines is to be lined, unless local flaps from nasal region can be turned inward.

Arm Flap

This flap has the advantage of avoiding facial scarring but it offers two disadvantages (1) color difference (paler than the face) and (2) cumbersome positions when being transferred These disadvantages must be carefully weighed before the choice is made

The outlining and preparation of the flap are as previously described (p 301) The donor area is the median surface of the upper arm. The

For insertion of cartilage grafts, for support and variation of lining, and for final formation of nostrils, see p 304

Deformities

The nose appears deformed if it differs in shape and in proportion from the normal characteristics of a race. A nose of normal size may be out of harmony with the rest of the face in a person with a retruding chin; and

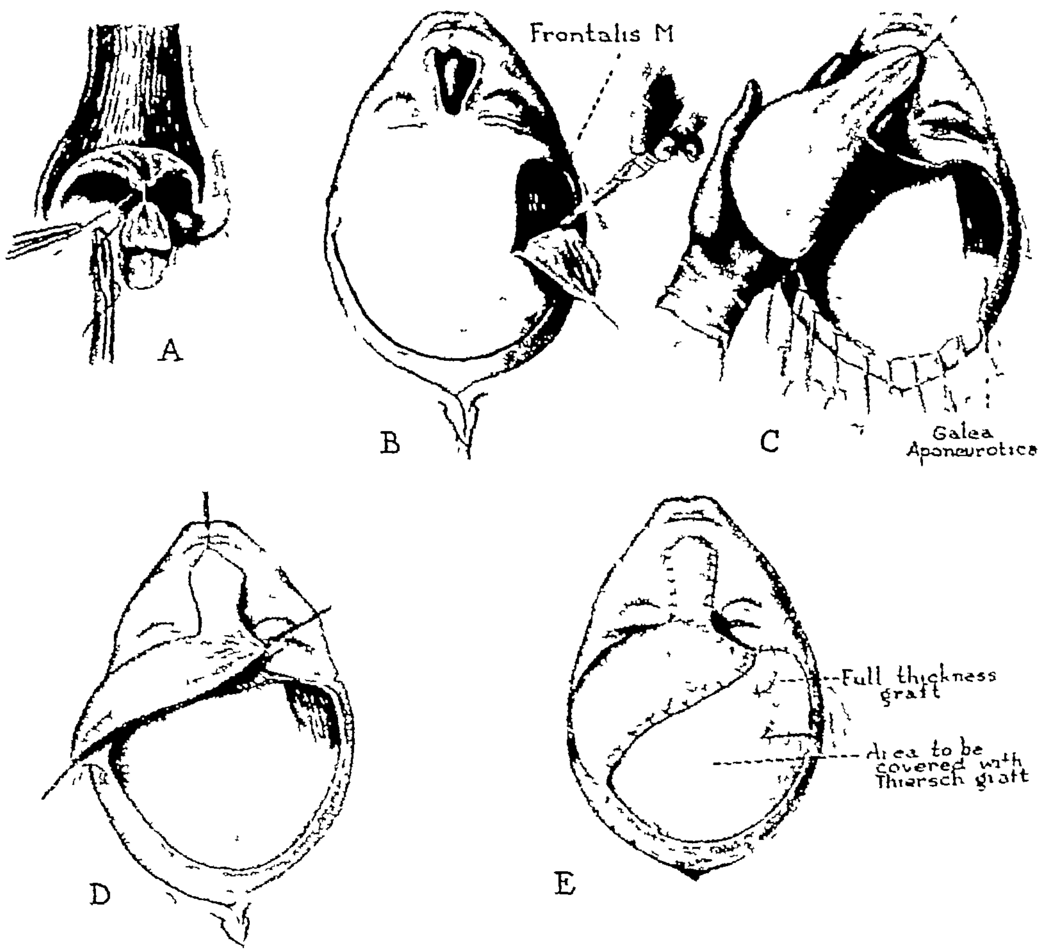


Fig 177 Technic of the scalping forehead flap—after Converse
(*A*) Nasal area prepared to receive the forehead flap A small flap, raised from the upper lip, furnishes tissue for reconstruction of the columella
(*B*) Outline of the flap The portion of the flap serving for the nasal reconstruction is raised, care being taken to preserve the frontalis muscle.
(*C*) The scalping flap is raised Note the splitting of the frontalis muscle, the frontalis is included in the base of the flap, a necessary precaution to preserve the blood supply
(*D*) The flap is turned down into its position of transfer The flap is folded, thus eliminating the raw area along its base.
(*E*) The area of the permanent defect on the side of the forehead is covered by a full-thickness retro-auricular graft which insures good color and texture match The temporary scalp defect is covered by a skin graft of intermediate thickness
(J M Converse Proc Roy Soc Med, 35 811, 1942, and V H Kazanjian and J. M Converse The Surgical Treatment of Facial Injuries Williams & Wilkins Co)

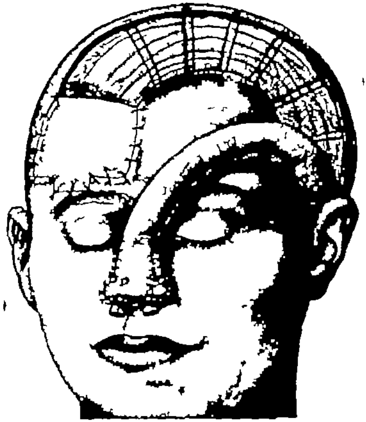


Fig. 175 *c* Pedicle of flap is tubed; donor site at forehead skin-grafted periosteum of skull covered with ointment dressing mattress sutures are laid to hold dressing in place and wound edges pulled together

Fig 176 Reduction of thickness of skin folds of columella and alae after all edema of flap has subsided.

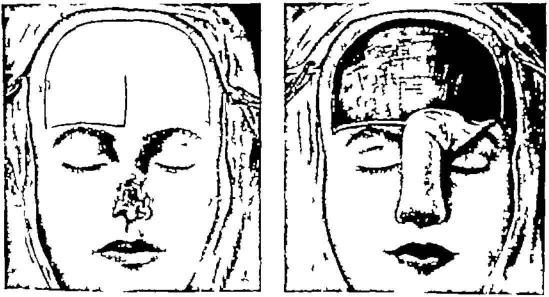
dle third of the distance between the hairline and the chin The width of the nose (base of the ala) equals the space between the inner canthi

The profile can be divided into three anatomical components the bony component (*a* in Fig 165), the upper cartilaginous component

Fig 179 Total loss of nose Reconstruction with arm flap Flap has been raised in stages from median surface of upper arm, donor area skin-grafted Arm is moved to face, and free end of flap is sutured to defect edges Arm is held in position with plaster cast. Flap is to be severed from its base after two weeks and its free end folded and sutured, as demonstrated in Figs 173, 175

(*b* in Fig 165), and the lower cartilaginous component (*c* in Fig 165) (Joseph) In a normal nose, all three components are of such proportions that they form a straight line from the root to the tip, and do not

an enlarged nose may look normal if it is not grossly inharmonious with other facial features. Hence, the indication for a corrective operation and the operative plan itself must consider the relationship of the nose and the rest of the face in every instance. If a deformity is very noticeable and improvement by surgical reconstruction is possible, the advisability of an operation is clear-cut. Far more difficult is the decision where the transition from normal to abnormal is slight. If such is the case, the surgeon must evaluate the patient's mental attitude carefully before making his decision, since even the finest surgical results may not please the patient. The assistance of a psychiatrist may be of great value.



a *b*

Fig. 178, *a*. "Horseshoe" flap for subtotal reconstruction of nose. Pedicle contains left supraorbital vessels.

b. Flap transplanted; donor area to be treated as in Fig. 175*c*. V-shaped separation of flap outlined. Latter facilitates smoother adjustment of flap and remainder of nose. (J. Penn, South African M. J.)

A careful general and local examination should precede the operation. The patient must be in good health and free of any focal infection. Photographs and in some cases casts of the face are of great aid in planning the operative procedures and in recording the case.

The object of the reconstructive operation is to bring the abnormal forms of a nose into harmony with the rest of the facial features. To achieve this, the surgeon must be able to imagine the final form of the nose. "Normal" and "abnormal" are terms which can be applied only in the light of the racial characteristics of the individual. The length of the normal average nose of an adolescent white person should equal the mid

Classification: Berndorfer quotes Dufourmentel's division of the various nasal deformities

1 Deformities due to insufficient skeletal support
  (*a*) Depression of the bony structures (saddle nose)
  (*b*) Depression of the cartilaginous framework (Negro nose)
  (*c*) Depression of bony and cartilaginous framework (fat nose)
  (*d*) Depression of the alae (nostril collapse)
  (*e*) Stenosis of the nostrils
  (*f*) Shortness of the alae
  (*g*) Shortness of the nasal tip

2 Deformities of the bony and cartilaginous framework from hypertrophy
  (*a*) Hypertrophy of the bony structure in the profile (hump nose)
  (*b*) Hypertrophy in frontal direction (broad nose)
  (*c*) Hypertrophy of the cartilaginous structures
    (1) Elongation of the septum
    (2) Prominence of the nasal tip
    (3) Depression of the nasal tip (wide nostrils)

3 Deformities due to injury to the bony and cartilaginous framework
  (*a*) Deviation of osseous structures
  (*b*) Deviation of cartilaginous structures
  (*c*) Deviation of nasal tip
  (*d*) Subluxation of the septum
  (*e*) Broadness of the nostrils

HUMP NOSE

A hump nose is a typical nasal deformity and, as a rule, can be satisfactorily repaired with rhinoplasty Removal of the hump, however, is insufficient in the majority of cases without adjustment of the remainder of the external framework Removal of the hump often causes broadness of the ridge, which requires narrowing, as well as reduction of the height of the ridge, which may make the nose appear too long, requiring shortening. The reduced height often causes prominence of the nasal tip, requiring reduction All these operative steps, which should be planned preoperatively, require an adequate exposure of the nasal framework

The procedure involves (1) exposure of the nasal framework, (2) removal of the hump, (3) narrowing of the nasal ridge, (4) shortening of the nose, and (5) reconstruction of the nasal tip The entire procedure is performed from intranasal incisions, and is based upon the ingenious work of Joseph Improvements have been added, and much has been written about this subject The most extensive compilation of references has been made by McDowell, Valone, and Brown Brown and McDowell have also published a monograph on rhinoplasty, a monumental piece of work

noticeably protrude or recede the nasal profile angle of about 20 to 38 degrees (30 degrees is ideal) and the nasolabial angle of 90 degrees. The nasal profile line is formed by the forehead chin line and the dorsum of the nose (Fig 180) The normal profile line becomes disturbed

a b

Fig. 180: Relation of nose to normal nasal profile angle.

a. Upper and middle part of nose extending beyond normal nasal profile angle while lower part of nose (nasal tip) is receding. b Nasal ridge between nasal tip and glabella markedly receding from normal profile angle.

If the three anatomical components protrude or recede the nasal profile angle singly or in combination In Fig 180 a the bony and upper cartilaginous components are protruding while the lower cartilaginous component (nasal tip) is receding If one includes the length of the nose and its tilt in this scheme the varieties of deformities become numerous

Exposure of Nasal Framework The incisions necessary for this procedure are bilateral intercartilaginous incisions combined with an incision of the membranous septum The intercartilaginous incisions are made first The lower border of the upper cartilage is visualized by raising the tip of the nose with a small blunt retractor, which is held with the index finger and thumb of the left hand, while the middle finger presses the ala inside (Fig 181) The mucous membrane is incised upon this ledge, starting posteriorly and reaching the tip cartilages anteriorly

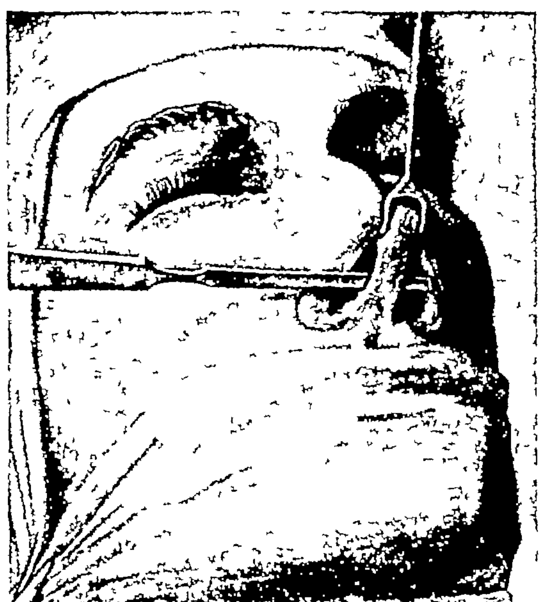


Fig 182 Severance of columella cartilages from free edge of septal cartilage through membranous septum (H May Am J Plast & Reconstruct Surg)

The fibers between the upper and lower cartilages are severed Thus, the lower border of the upper cartilage becomes exposed A similar procedure is performed on the other side With a curved pair of dissecting scissors, introduced through one of the incisions, the covering skin is freed from the entire nasal framework, laterally as well as anteriorly The scissors are withdrawn A two-pronged hook is inserted into the nostrils to elevate the nasal tip (Fig 182) A pointed knife, Parker No 11, is pushed through the interspace between the columella cartilages and the free edge of the septal cartilage, the pointed knife is now replaced with a dull-tipped knife, and the membranous septum is severed from the bottom to the tip (Fig 182) At the tip, it is combined with the intercartilaginous incisions The curved pair of scissors are inserted through one, later through the other, intercartilaginous incision, and led from the root of the nose along the ridge, over the nasal tip and through the

Technic (Cases 44–47 pp 908–911) The operation can be performed under local as well as endotracheal anesthesia. Both the outside and the inside of the nose are prepared The hairs of the nostrils are cut with scissors the face is gently washed with soap and water or pHisoderm and the mucous membrane is painted with one of the nonirritating antiseptic solutions (Arnold s solution see p 4) The nose is then packed on both sides with plain gauze

Fig. 181: Preparation for intranasal incisions in repair of hump nose. Lower border of upper lateral cartilage, along which intercartilaginous incision will be made, is visualized. (H May Am. J Plast. & Reconstruct. Surg.)

If local anesthesia is used it is preceded by packing each nasal fossa with a ½ inch strip of gauze which is wrung dry after immersion in a solution of equal parts of 10 per cent cocaine and 1 1000 epinephrine As a rule 5 or 6 cc. of the solution will suffice. (If any solution is left, it should be discarded immediately to prevent confusion with the procaine solution used for local anesthesia. Still better and securer is it to color the cocaine solution Injected cocaine may cause instant death) The packing is removed after forty minutes The local anesthetic (30 to 40 cc. of 2 per cent procaine solution to which 10 drops of 1 1000 solution of epinephrine is added) is injected first around and into the infraorbital foramina then across the floor of the nostrils The needle is now inserted intranasally between the upper and lower lateral cartilages and advanced subcutaneously to infiltrate the dorsum and glabella it is then again inserted at the base of the ala and the entire lateral wall of the nose is infiltrated The same procedure is performed on the other side

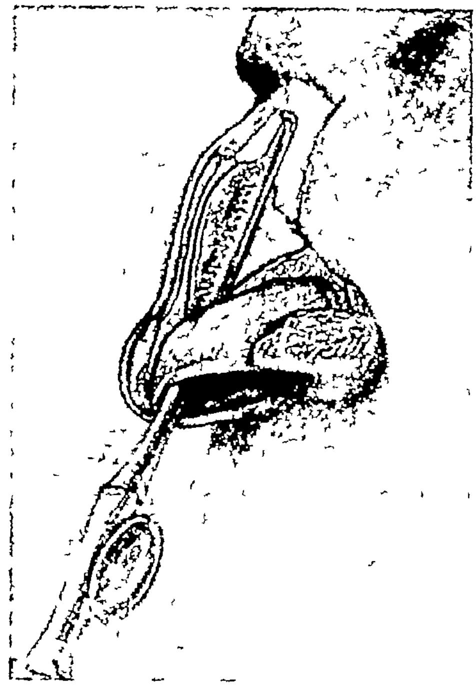


Fig 185 Removal of hump with straight saw (H May Am J Plast & Reconstruct Surg)

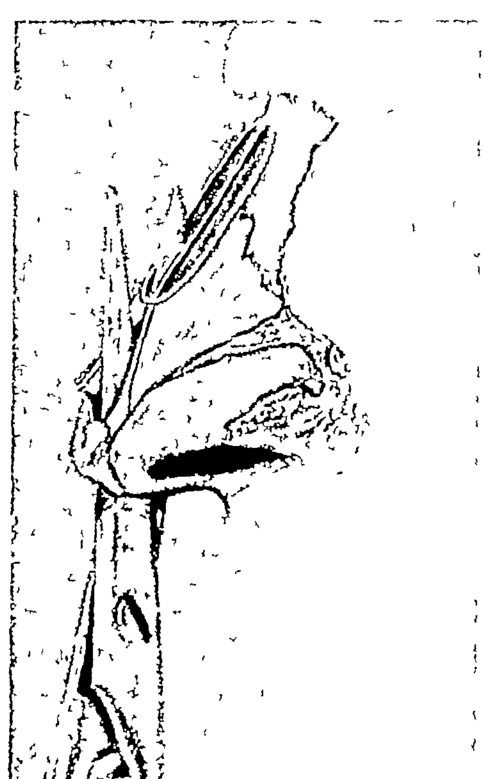


Fig 186 Remaining attachments of upper lateral cartilages and septum are severed with pair of straight scissors (H May Am J Plast & Reconstruct Surg)

incision between columella and septum this is to make certain that no residual bands are left.

Removal of Hump A pointed, slightly curved double-edged knife is inserted through the right intercartilaginous incision to incise the periosteum of the lateral wall of the anterior nasal bone (Fig 183) The Joseph periosteal elevator is inserted into the periosteal incision and the periosteum is elevated from the ridge and the lateral walls of the nasal bones along the line of the hump to be removed—closer however to the

Fig. 183 Insertion of pointed knife through right intercartilaginous incision and incision of periosteum of nasal bones. (H. May Am. J Plast. & Reconstruct. Surg.)

Fig. 184: Insertion of periosteal elevator to sever periosteum along the line of hump to be removed, closer toward face than the hump (H. May Am. J Plast. & Reconstruct. Surg.)

Narrowing After removal of the hump, an elliptical defect is left, which usually broadens the nasal ridge (Fig 188) To narrow it, the frontal processes of the maxilla, together with the nasal bone, must be mobilized to permit a median displacement of the nasal bones This is done as follows

The frontal processes of the maxilla, upon which the nasal bones rest, are severed, this can be done with a nasal saw or with an osteotome (Fig 188). It is important to sever them flush with the face, if severed on a

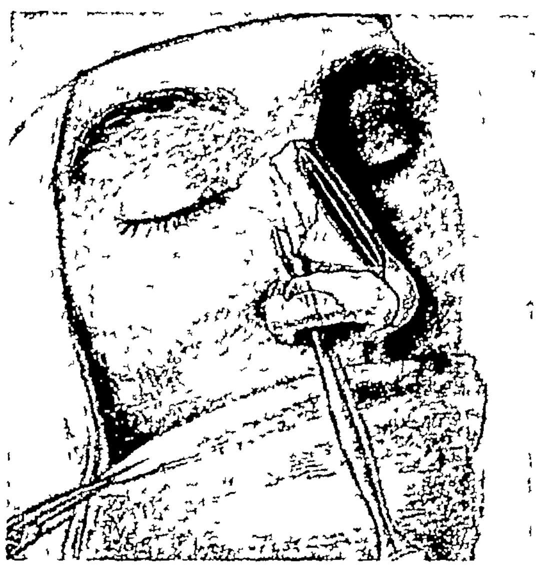


Fig 188 To narrow elliptical defect of nasal ridge frontal processi of maxilla are severed. (H May Am J Plast & Reconstruct Surg)

higher level, a bony ridge may become visible along the lateral nasal wall Before the bones are severed, the skin and soft tissues are elevated along the base of the nose A small intranasal incision is made at the right base of the anterior process of the maxilla at the pisiform opening. The small Joseph periosteal elevator is pushed through the incision along the base of the lateral nasal wall, and the soft tissues are elevated. If an osteotome is used for severance, it is held in the right hand while thumb and index finger of the left hand protect the orbits, an assistant, with gentle blows on a mallet, drives the osteotome upward If a saw is used (the bayonet type after Joseph), it is introduced with the help of Joseph's guiding elevator along the lateral wall of the frontal process of the maxilla, and the frontal process is sawed through in its entire length The remaining anchorage of the nasal bone at the frontal process is now fractured Before this is done, it may be necessary to sever or remove a segment of bone from the upper angle of the nasal bones with an osteotome (Fig 189) to loosen the upper attachments and facilitate narrowing, if a seg-

face than the hump (Fig 184) The same procedure is performed on the other side. The hump is now removed preferably with a straight nasal saw which is introduced through the left intercartilaginous incision (Fig 185) The saw must be held horizontally to sever both nasal cartilages in the same plane A guiding finger is placed upon the right side to prevent perforation of the skin Any remaining attachments along the cartilaginous ridge can be severed with the angled drawing knife The hump is now removed with a grasping forceps Although parts of the upper lateral carti

Fig. 187: Reduction of cartilaginous septal ridge. (H May Am J Plast. & Reconstruct. Surg.)

lages which join the cartilaginous septum may have been removed with the hump remaining parts may still be attached to the septal ridge these are now severed from the latter with a pair of straight scissors which are held closely hugged to the septum (Fig 186) With a nasal rasp the sharp bony edges are smoothed the debris is flushed out with water squirted from a bulb syringe. The skin over the dorsum is now lifted with a long nasal retractor to permit inspection of the operative field should the cartilaginous ridge of the septum still be higher than desired it can now be reduced with a pair of straight scissors (Fig 187) The anterior edges of the upper lateral cartilage if too long and protruding can be clipped at this stage

90 degrees will be more pleasing) If the nose appears too long, a quadrilateral strip of the free end of the septal cartilage is removed Should, however, the anterior portion of the columella be "hanging," it is necessary to remove a triangular strip from the free end of the septum (base of the triangle anteriorly, tip toward the nasal spine) unless the hanging is due to excessive protrusion of the columellar cartilages, a situation that must be corrected first by proper trimming of the cartilages.

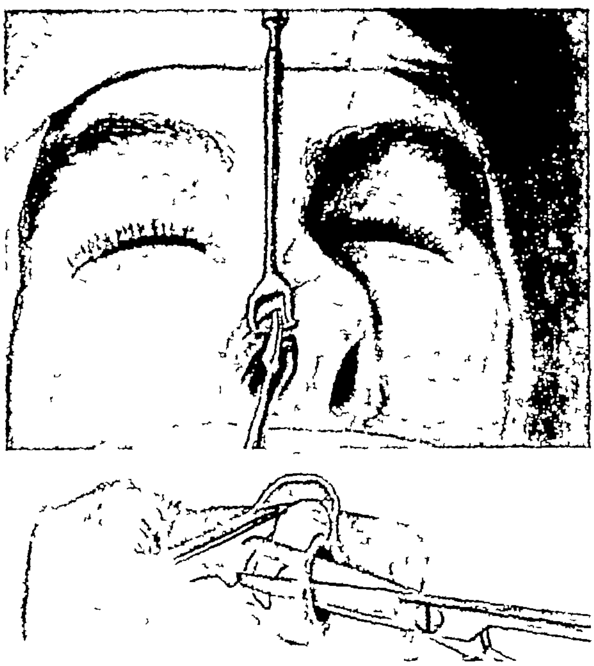


Fig 190, *a* Reconstruction of nasal tip Intracartilaginous and transfixion incision is visible posteriorly Alar cartilage to be exposed from rim incision Nostril being steadied during the incision with ribbon retractor
b With dissecting scissors skin is freed from alar cartilage (H May Am J Plast & Reconstruct Surg)

If the upper lip is too short due to protrusion of the anterior nasal spine of the vomer at the columella-lip junction, a quadrilateral strip of septum, including part of the anterior nasal spine, is removed. The columella is then suspended to the septum with a suture which passes through the base of the columella and through the skin and then back through the same suture opening and through the septum (Fig 193)

In all these excisions, one ought to be rather conservative, significant correction is often achieved after removal of small amounts of tissue. With a temporary stay suture, the columella is fastened to the free edge of the septum, thus shortening the midline of the nose It now becomes noticeable that the lower rim of the upper lateral cartilages protrude into the nose through the intercartilaginous incision because the side walls are too long These are shortened by excision of the protruding portions.

ment of bone has been cut out it is removed with a hemostat. The mobilization of the nasal bones is best done by inserting an osteotome between the septum and the nasal bone using the septum as a fulcrum the lateral nasal walls are pushed or broken outward or the lateral walls are grasped with Walsham s nasal forceps and fractured outward. A similar procedure is performed on the other side The mobilized nasal bones are shifted into the midline by manual pressure (with the thumbs) thus narrowing the nasal ridge

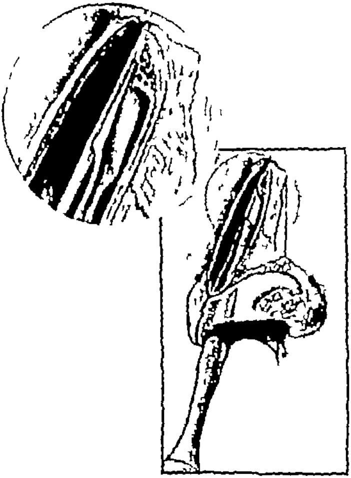


Fig. 189: Removal of triangular segment of bone of upper angle of nasal bones to loosen upper attachment of later and facilitate narrowing. (H May Am. J Plast. & Reconstruct. Surg.)

Shortening of Nose This may or may not be necessary The length of the nose is determined by the length of the septum and the thickness of the columella Ideally the length of the nose should equal the middle third of the distance between the hairline and the chin and the colu mella lip angle should be about 90 degrees or slightly more depending upon the length of the upper lip (in short upper lip a tilt greater than

during the incision The rim of the tip cartilage is exposed, and the covering skin is freed from the cartilage (Fig 190) with a pair of dissecting scissors The height of the tip cartilage is reduced by excision of a portion of the dome. This is done as follows: Cartilage and mucous membrane are incised near the median crus just below the tip (Fig 191). The portion of cartilage to be excised is freed from the underlying mucous membrane (Fig 192), the exposed portion of cartilage is excised; the mucous-membrane flap is left behind, so that after proper shortening it can be reattached (Fig 193) The same procedure is performed on the other side, care being taken to make the excisions of equal size

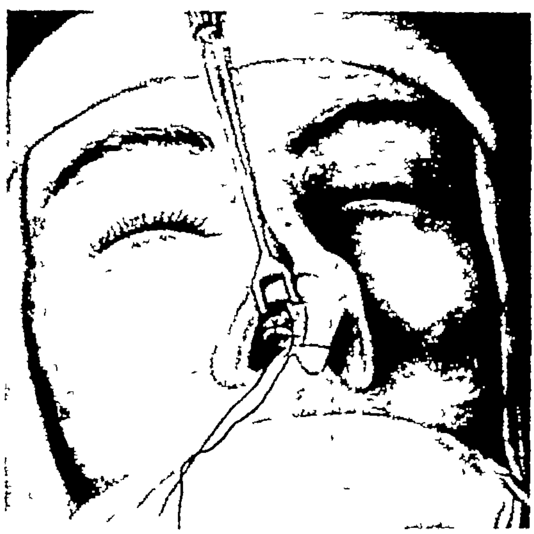


Fig 193 Intranasal sutures and transfixion suture of columella and septum (H May Am J Plast & Reconstruct Surg)

If the lower lateral cartilages (the tip cartilages) require reduction not in height but in width, to make the tip more pointed, the excision does not include the median portion of the dome supplying the height, only that part of the dome which gives breadth

If reduction in bulk and height of the lower lateral cartilages is necessary, excision of the upper rim of the cartilage can be combined with the excision of the cross strip, so that the total excision consists of the removal of a single piece shaped like a hockey stick The cartilage is exposed by eversion and held everted on a pair of scissors (Fig 194). The underlying mucous membrane should be left intact After the cartilages are repositioned, the rim incision is closed. The mucous membrane of the columella is sutured to that of the septum

For correction of other tip and nostril deformities, see p 326.

Dressing and Immobilization: The packing is removed, the nasal vaults are cleansed with suction apparatus, and are packed again lightly

Reconstruction of Nasal Tip After reduction of the height and the length of the septal-osseous framework of the nose the tip as a rule is prominent and needs reduction If the tip is not only prominent but wide and bulky it must be reduced in height as well as in width and bulk The lower lateral cartilages are exposed from an incision along the rim of the nostrils just within the nose The insertion of a ribbon retractor such as depicted in Fig 190 is of help to steady the nostril rim

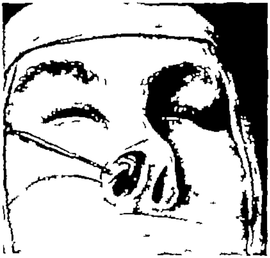


Fig. 191: Cartilage and mucous membrane incised near median crus below tip. (H May: Am. J Plast. & Reconstruct. Surg.)

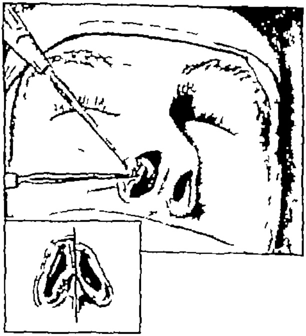


Fig. 192: Portion of cartilage to be excised freed from the underlying mucous membrane. Dotted lines of lower insert shows incision along which dome is to be excised. (H. May: Am. J Plast. & Reconstruct. Surg.)

PROCEDURE FOR MORE ADEQUATE EXPOSURE OF NASAL FRAMEWORK In the majority of cases, the classical intranasal incisions that derive from Joseph give adequate access to the nasal framework for the various steps of rhinoplasty The Réthi incision, however, has been found extremely

Fig 195 Immobilization of nose with medium-sized cork, which has been halved Each half is held firmly attached to nasal wall with adhesive strips which cross each other at forehead and below columella One or two more adhesive strips are placed transversely over corks and attached to cheek

valuable when the cartilaginous framework, particularly of the nasal tip, is markedly and irregularly deformed and requires extensive reduction The method is referred to in various textbooks, but its advantage of affording a much more adequate exposure of the lower half of the nose has not been widely appreciated.

Technic (Réthi) (Fig 196, Case 43, p 906) The Réthi procedure starts with a transverse incision through the columella. First, however,

with 1 inch strips of ointment gauze. One hundred and fifty units of hyaluronidase are injected into each side of the nose near the median canthi to prevent postoperative swelling Final molding of the nasal walls and application of an immobilizing dressing follow Of all the materials recommended for this purpose the author finds the pressure dressing with halved corks efficient and simple A medium sized bottle cork is halved longitudinally Each half is placed against the lateral wall of the nose including the tip and held in this position with adhesive strips

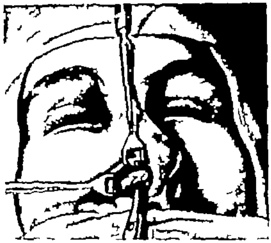


Fig. 194 Another method of reduction of heights and bulk (width) of alar cartilages—after J B. Brown and F McDowell. Cartilage is exposed from incision as in Fig. 190 and everted on a pair of scissors. Inverted hockey stick like incision for removal of cross strip of cartilage and upper rim is outlined. Underlying mucous membrane should not be excised.

(Fig 195) The strip to hold the left cork in place starts on the right side of the forehead and proceeds over the left cork, then below the columella to the right side of the cheek Readjustment of the strip may be necessary to place the flat side of the cork firmly and in its whole length against the nasal wall A vice versa procedure is performed with the right cork One or two adhesive strips are placed transversely over the corks and attached to the cheek to avoid depressing the nasal tip, they should not run over it. A piece of gauze is taped below the nostril for absorption of drainage

After Treatment The dressings are changed on the third postoperative day The packings are removed the skin over the nose and the cheeks is gently cleansed with hydrogen peroxide solution and cold cream the corks are firmly reapplied in the original manner The dressings are removed on the fifth postoperative day The nasal vaults are gently cleansed with swabsticks soaked in hydrogen peroxide solution and the patient is discharged into ambulatory treatment

nostril, and circumscribes the anterior half of each rim With the aid of traction sutures and under sharp and later on under blunt dissection, the skin overlying the median crura and the lower lateral cartilages is mobilized and retracted until the upper lateral cartilages are reached. This exposure offers an excellent access and view of the entire nasal framework. Whatever the nature of the deformity, the correction can be carried out under direct vision

To separate the lower from the upper lateral cartilages, bilateral intercartilaginous incisions are made, unless they have already been made as the initial steps in exposure of the nasal framework in total rhinoplasty. After completion of the correction, the skin is reflected into its former position The first suture of the wound edges is laid through the scratchmark, followed by suturing of the remainder of the wound edges

DEFORMITIES OF NASAL TIP

See also p 321

Depressed (Wide) Tip: The tip cartilages are exposed from a Réthi incision The lateral crura of the lower lateral cartilages are severed in the desired level (Fig 196) Care must be taken to leave the underlying nasal mucous membrane intact The mobilized lateral crura are then everted and sutured back to back (Kazanjian).

Depression (Shallow) above Tip: This depression is situated over the cartilaginous ridge, i e , where the upper lateral cartilages join the cartilaginous septum The upper lateral cartilages are exposed from a Réthi incision (Fig 196), and are severed lateral to their insertion to the cartilaginous ridge. They are now everted and sutured back to back (Straith)

Cleft Tip: In cleft tips, the soft tissues between the cartilages are removed, the width is reduced by excision of part of the dome from the lateral crura, and the cartilages are then firmly sutured together

Retracting Tip: When the nasal tip is retracted, the columella is severed from the free edge of the septum and then pulled forward on the edge of the septal cartilage by an advancing mattress suture which reaches the columella at a more posterior level than the septal cartilage This simple procedure, however, is usually not sufficient. It may take wide undermining of the ridge of the nose and shortening of the nose to accomplish a permanent result (see p 314)

DEFORMITIES OF NOSTRILS

See also p 321.

Bulging Nostrils: If the nostril is too bulging and outward curved at its base, a crescentic piece of ala is removed from its base with a pair of

it is wise to make a longitudinal scratch with the scalpel through the middle of the columella Later on this will facilitate alignment of the wound edges A transverse incision is made about 2 or 3 mm ($\frac{1}{10}$ or $\frac{1}{8}$ inch) posterior to the columella alar angle this penetrates the skin and to but not through the median crura Two small arteries are encountered at each edge of the incision and are ligated and severed The direction of the incision is now changed abruptly toward the columella alar angle and from here it runs parallel to and just inside the rim of the

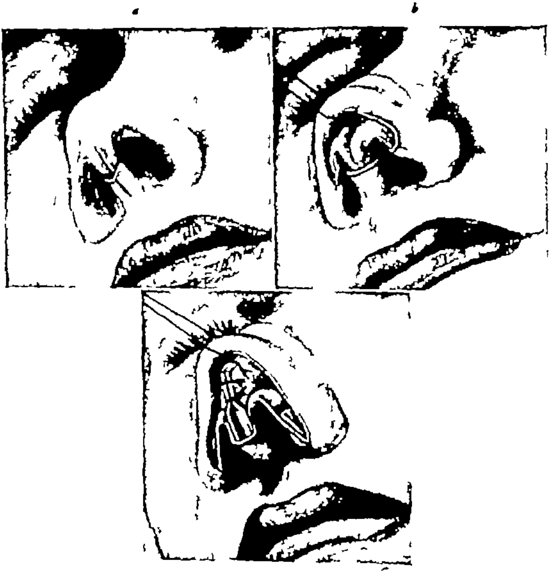


Fig. 196, a Correction of retracted nasal tip (after Karanjian and Straith) Exposure of lower and upper lateral cartilages (after Réthi) Intravestibular incision (internal incision) parallel to and just within nostril is combined with external incision across middle of columella. Small longitudinal line crossing columellar incision indicates landmark which should be scratched upon skin to facilitate accurate approximation later

b: Exposure of lower lateral cartilages by reflecting skin upward.

c: After nasal mucous membrane has been dissected away lateral crura are severed in proper level and everted and sutured back to back (Karanjian, Straith)

divided tip cartilage is dissected free from the underlying nasal mucous membrane and everted and sutured to the median crus on the other side Trimming down the height of the tip cartilage on the other side (p 321) may be of help The skin draped over the newly arranged framework may also need adjustment by excision of a crescent-piece from above the alar border of the tip (Fig 96) Gelbke adjusts it by excision of Burow-type of skin triangles from either side of the tip Obliquity of the columella may also cause nostril asymmetry For its correction, see below

Atresia of Nostrils: This condition is due to destruction or absence of the mucous-membrane lining, it is either acquired or congenital If congenital, it is usually associated with other deformities of the nose, requiring more or less extensive reconstructive operations If, however, the condition is due only to destruction of the mucous-membrane lining, the operation is simpler It starts with excision of all scar tissue and formation of a normally shaped vestibule A mold of dental compound is now formed of the latter with overcorrection, a thick split graft wrapped around it, raw surface outward, and inserted The mold can be held in place by adhesive plaster or by a special dental prosthesis fastened to the upper teeth The mold remains in place for ten days, it is then changed and replaced by another one, which is perforated to allow nasal respiration. The mold should be cleansed daily, and should be worn for at least two months to counteract shrinkage In some cases of severely contracted nostril, better results are obtained by introduction into the floor of the nostril of a pedicled skin flap from the cheek alongside the nose

DEFORMITIES OF COLUMELLA

Short Columella: The columella is freed from the lower edge of the septal cartilage by incising the entire membranous septum The incision is continued toward the lip to form a V-shaped flap, which will lengthen the columella at the expense of the philtrum of the lip The nasal tip is raised and the columella fastened to the septal cartilage, the wound edges of the lip are undermined and sutured together, then follows suturing of the skin edges of the columella. For more extensive cases, a similar technic, as described on p 245, is applicable.

Oblique Columella: The columella may be displaced at its base or near its attachment at the nasal tip The displacement is corrected according to the N-type of operation (compare with the method described on p 281)

SADDLE NOSE

Saddle nose is due to destruction or displacement of the framework, particularly the ridge, of the nose.

In most cases, it is of traumatic or syphilitic origin, rarely congenital

specially curved scissors which are inserted directly at the nasofacial groove. The latter can be better visualized by pressure upon the nostril After suture of the wound the suture line will come to lie along the groove of the base of the nostril

Narrow Nostril Floor· If the floor of the nostril is too narrow a triangular flap is made just lateral to the nostril (base toward the lip and tip toward nasofacial groove) The base of the nostril is severed as previously described and the flap is switched from the outside to the inside (Fig 197)

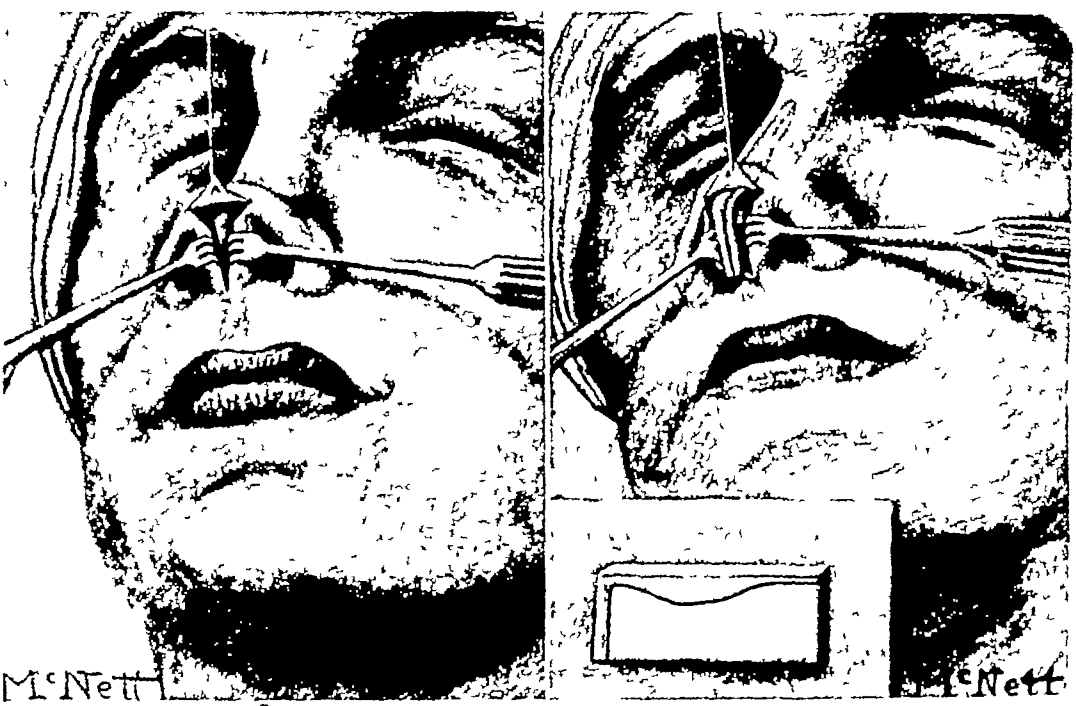
Fig 197 a: Widening of floor of nostril a triangular flap made just lateral to base of nostril.
b: Base of nostril is severed and triangular flap switched from outside to inside.

Wide Nostril Floor· When the floor is too wide one may reverse the method just described. Another procedure is to excise a diamond shaped piece of skin from the nasal floor followed by wide undermining of the wound edges and suture of the skin

Asymmetry of Nostrils (See also pp 244–245) This is usually secondary to cleft lip repair (An excellent description of the pathological anatomy of cleft lip nose has been made by Huffman and Lierle) The lower lateral cartilage on the cleft side is below (posterior to) the level of the other side the dome on the affected side is wide causing a wide columella-alar angle and the median crus is shorter than on the other side Adjustment is made by repositioning the tip cartilage on the affected side. Wide exposure of both tip cartilages such as the Réthi incision particularly well affords (Fig 196), often causes some degree of repositioning As a rule however additional steps are necessary to build up the height of the columella on the cleft side and narrow the width of the dome The lateral crus on the affected side is divided as in the procedure depicted in Fig 196 b (the division should not be made too far lateral rather on the lateral side of the dome) the median portion of the

smooth. The graft is inserted so that its upper edge rests against the glabella. The incision is now closed (Cases 50–52, pp 915–917).

If also the columella needs to be supported to maintain the prominence of the nasal tip, a Y-shaped incision is made, which is provided by a V-incision below the nasal tip and a longitudinal extension along the columella. From this incision, the entire columella is incised in the midline, in addition to the undermining of the nasal ridge, the cartilages of the columella are separated from each other, and posterior to them a



a *b*

Fig 198, *a* Reconstruction of traumatic saddle nose and depressed nasal tip by insertion of angulated cartilage graft V-shaped incision is made below nasal tip with longitudinal elongation along columella. Columellar cartilages are retracted, exposing free end of septal cartilage Triangular skin flap is lifted Ridge of nose is undermined *b:* From large block of rib cartilage, angulated piece of cartilage is carved out Its longer arm is inserted into dorsum of nose, the shorter arm posterior to columella resting upon nasal spine of maxilla

canal is prepared in the membranous septum reaching from the tip to the nasal spine of the maxilla (Fig 165)

A single piece of cartilage is carved in an angular manner with a long arm going into the dorsum and a short arm posterior to the columella of the nose, resting upon the nasal spine of the maxilla To obtain sufficient material for this purpose, a large block of cartilage is removed from the fused cartilage between the seventh and ninth ribs, consisting of the full thickness of the ribs and equaling in width the distance from the

Traumatic Saddle Nose

In saddle nose resulting from nasal injury the bony framework is broad and flat if the breadth is not too great the depression of the nasal ridge is built up in one stage with a bone or cartilage graft. Otherwise it may be necessary to elevate the displaced nasal bones and to narrow the abnormally wide base and ridge of the nose before introducing a graft If this is the case a two-stage operation is necessary

Stage 1 (Reduction of Broad Nose) From an intranasal incision (see p 314) the nasal bones are exposed and separated anteriorly from their attachment at the septum by incising the bone on either side of the septum with the special straight broad dorsal saw (as devised by J B Brown and McDowell) from inward-outward The upper lateral cartilages are then severed from their dorsal attachment to the septum and reduced in width Then from an incision along the lower border of the apertura piriformis the nasal bones are separated posteriorly through the frontal process of the maxilla (Fig 188) The bones are then brought into a more median position to approach each other in the midline above the nasal ridge thus converting width into height they are held in place with a cork dressing (Fig 195) or with a mattress suture of stainless-steel wire which is placed through either nasal bone and tied over lead plates

Stage 2 Three weeks later a properly shaped piece of cartilage is inserted to fill out the depression If only the nasal ridge is depressed a simple graft is transplanted (Cases 50–52 pp 915–917) if nasal tip and columella are also depressed a columellar strut must be provided in the form of a hinged graft. The author prefers autogenous cartilage grafts since they can be easily obtained and shaped and also since they are not likely to become absorbed The writer also prefers outside incisions the objection to inside incisions is that a tissue as delicate as a graft should not be inserted through regions which never can be made aseptic.

Technic (Fig 198) From a V-shaped incision below the nasal tip the skin of the ridge of the nose is undermined first with a small knife then with a pair of curved scissors until the nasal bones are reached from there the undermining is done subperiosteally The undermining should be exactly in the midline and not too far laterally At the glabella the periosteum is raised to form a pocket Hemostasis is now applied by pressure

The cartilage graft is taken and prepared as described on p 59 The perichondrium is removed The upper part of the graft is tapered so as not to obliterate the frontonasal angle The lower part is also tapered to conform with the tip. The dorsum of the graft should be rounded and

the underlying bone The nasal skin can now be stretched forward to normal size and position The resulting raw surface at the inside must be covered with a skin graft to prevent subsequent shrinkage.

Stage 1. A dental prosthesis to fit the upper teeth is designed by a dentist To the center of this prosthesis, a removable flat splint is applied, which is broader at its end The prosthesis is cemented to the teeth preoperatively.

Fig 199 Reconstruction of syphilitic saddle nose (after Gillies) (see text) (From H D Gillies Deutsche Ztschr f Chir)

An incision is made along the upper gingivobuccal sulcus from one fossa canina to the other All soft tissues are severed until the nasal cavity is reached. Now while the nasal tip is pulled forward, the columella and the soft tissues of the nose—the septum is absent—are severed from the bone mediad and laterally until the root of the nose at the glabella is reached.

A mold of dental compound is made (see p 37) to fit the new nasal cavity with slight overstretching of the skin. After packing the piriform opening to prevent escape of the compound into the posterior nasal

tip to the nasal spine (Fig 198 *insert*) Another good source for a strut is a bone graft from the crest of the ilium removed with converging chisels (Seeley) The convergence is so arranged as to be entirely within the confines of the inner and outer table of the ilium The graft is then carved either L shaped or if much of the cartilaginous septum is destroyed a broader piece is left attached in shape of a rudder of the common sailboat The cartilage graft is inserted as depicted in Fig 198 *b* In case of a bone graft one should make sure that the upper part of the graft comes to lie subperiosteally hence prior to the insertion a chisel is inserted subperiosteally for the removal of a thin section of dorsal nasal bone for creation of such a pocket.

If there is a tendency of the graft to slip a straight needle is pierced through skin graft, and underlying septum thus anchoring the graft in a simple way The needle is removed after forty-eight hours

In some cases only the cartilaginous ridge is depressed as one sees it after an abscess of the septum or after too extensive submucous resection of the septum In slight depression associated with retraction of the nasal tip the method of Kazanjian-Straith is suitable for correction (see Fig 196) If unassociated with retraction of the tip the depression is best corrected by a dermal graft which is inserted through the previously mentioned V incision (Straatsma) For removal of dermal grafts see p 42 For deeper depressions, however one must resort to transplantation of a small cartilage graft.

Syphilitic Saddle Nose

Before any operative work is done one must be sure that the disease has been brought to a standstill as a matter of fact it is best to play on the safe side and submit the patient to thorough preoperative antiluetic treatment whether his Wassermann reaction is positive or negative

Gillies divides the deformities of the syphilitic nose in three groups

1 Syphilitic deformities from small losses of the cartilaginous septum which are corrected by insertion of a cartilage graft as previously described
2 Syphilitic deformities due to destruction of the framework and lining
3 Syphilitic deformities due to destruction of skin framework, and lining

LOSS OF FRAMEWORK AND LINING

In these cases it is necessary first to replace the lining of the nose and subsequently the framework.

Technic (Gillies) To restore the nasal tip and alae to their normal position it is necessary to sever them from the apertura piriformis and

two-stage method of repair In the first operation, the excess skin overlying the depressed median groove is excised, the alar and lateral cartilages are mobilized and sutured together, and the wide columella is adjusted Any dermoid cysts are removed If median cleft lip is present, it is repaired at the same time In the second stage, the bony ridge of the nose is fractured and narrowed, and, if necessary, a rib cartilage is introduced to fill the saddle depression Narrowing of the broad nose and some reduction of the saddle depression greatly reduce the deformity and make wide separation of the eyes and the broad head less noticeable Peer states that in all his patients the rib graft grew with the general growth when the operation was performed in childhood and a rib graft was used.

DEFLECTION OF NOSE

Deflections of the nose are either congenital or due to malunited fractures In the former case, the entire nose may be deflected toward one side, in deflections due to trauma, the osseous or the cartilaginous part may be involved singly or may be bent in different directions, resulting in a twist of the nose There is, however, hardly any deflection where the cartilaginous septum is not involved A correction must attack the external deformity as well as that of the septum Unless the latter is straightened, the external deformity will recur. Trendelenburg, Goodale, and Joseph have done the pioneer work upon which the present reconstructive technic is developed A good review of the subject has been provided by Elsbach

Technic. *Osseous Structures* The piriform openings are tightly packed with plain gauze An intranasal incision is made along the lower border of the apertura piriformis, skin and periosteum are now elevated from the lateral surface of the nasal bone, and the frontal process of the maxilla is severed as demonstrated in Fig 188 The same procedure is performed on the other side A gauze pad is now laid upon the deviated or convex side, and, with the thumb, pressure is exerted upon the osseous structures of this side to sever the frontonasal attachment and fracture the perpendicular plate of the ethmoid If the frontonasal attachment cannot be broken by manual pressure, a small incision is made over the root of the nose, just below the glabella, and the frontonasal attachment—together with the perpendicular plate of the ethmoid—is severed with a small chisel The nose is now shifted into the midline

In more severe cases of deflection, there is a discrepancy in the length of the nasal bones; the concave side is longer than the other This can be rectified by shortening the elongated bone either at the base or along the ridge The bone is shortened along the ridge if the deflection of the

spaces, the softened compound is pressed through the buccal incision into the nasal cavity with one hand while the other one molds the compound from the outside. While the compound is still soft, the removable splint is warmed, pushed into it, and screwed to the dental prosthesis After the mold has become hard splint and mold are removed It is recommended that one make a second stent at this time from which a permanent acrylic stent is made later on The stent is covered with a thick split graft in the usual way (see p 37) and reinserted after removal of the nasal packing the splint is screwed to the prosthesis (Fig 199) The usual after treatment is carried out as described on p 37

After two weeks the stent is removed and cleansed The cavity is thoroughly irrigated with hydrogen peroxide and isotonic saline solution any excess graft is removed and the stent this time the acrylic stent, is reinserted From then on the same procedure is repeated every other day

Stage 2 After two months a cartilage graft is transplanted as previously described care must be taken not to perforate the new nasal lining while forming the canal for the graft. The opening between mouth and nose can be closed in the same sitting by simple denuding and suturing the wound edges

LOSS OF SKIN FRAMEWORK AND LINING

The reconstructive work in these cases is similar to that used for subtotal or total rhinoplasty

In such cases however in which columella nasal tip and parts of the skin of the dorsum of the nose are preserved—that is, the middle and upper portions of the nose destroyed—a transverse incision is made above the lower cartilaginous vault through the full thickness of the nasal wall The lower portion is now pulled into normal position The resulting defect is covered with a lined forehead flap which is pedicled in the median third of one eyebrow (p 298) or a sickle flap as described on p 300 The lining may be provided by turning over a local flap (Nélaton and Ombredonne Lexer) A few weeks after the division of the pedicle of the flap a cartilage graft is transplanted

BIFID NOSE

Bifid nose, or cleft nose is a rare congenital deformity Owing to its rarity and the complexity of its treatment it will be considered only briefly The reader is referred to the excellent articles on this subject by Webster Demming Peer Gelbke and others All authors agree that surgical correction should be started at an early age Peer describes his

membranous septum parallel with the free edge of the lower border of the dislocated septal cartilage, the mucous membrane is dissected away and reflected from the septal cartilage on each side until the site of the angulation of the septum is reached At the angle of the deflection, the cartilage is incised vertically Then the dislocated portion of the septum

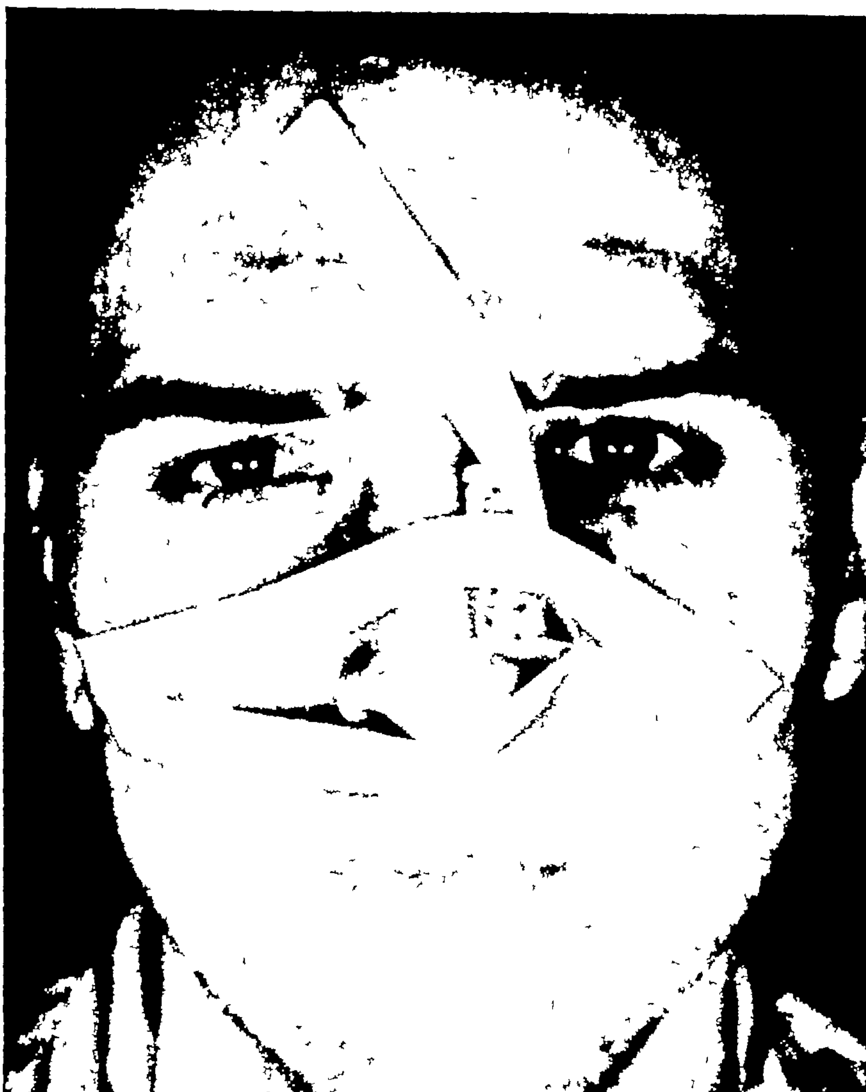


Fig 200 Immobilization of nose after its severance for correction of deviation Medium-sized cork is halved longitudinally Its flat side is placed upon the formerly deflected side and held firmly with adhesive strips, pulling nose toward corrected side

is separated from its false attachment at the maxilla with a small chisel The thus mobilized septal cartilage, which is now as free as a graft, is reduced to normal position beneath the nasal tip, elevating the latter. It is sutured in this position with a mattress suture to the cartilages of

nose is accompanied by a hump If this is the case the hump is removed first (see p 815) in such a way that more of it is taken off the elongated side. The frontal process of the maxilla on the short side is now severed (Fig 188) and shifted mediad This alone without severing the other side may overcome the deflection otherwise the other side must also be severed and molded into correct position. If a hump is absent and the elongated side must be shortened a triangular piece of bone should be removed from the frontal process of the maxilla on the long side with its apex at the frontonasal suture and its base at the apertura piriformis From an intranasal incision described above the anterior process of the maxilla is freed from its periosteum laterally and the nasal mucous membrane medially the strip of bone is sawed out with the nasal saw making the upper saw cut first. The bone is withdrawn with a grasping clamp The anterior process of the maxilla on the short side is now severed the frontonasal attachment may need severance (see above) and the nose is shifted into the midline, followed by repair of the deviated septum

Cartilaginous Structures In nasal deviations the cartilaginous septum is also deviated, dislocated or twisted, and unless it is restored to its normal position external deviation will recur If the entire septal cartilage is dislocated from its midline insertion on the nasal floor the entire cartilage must be freed anteriorly posterior and above (Case 49 p 914) If in the first phase of the operation (see above) a hump was removed the anterior attachments of the septum along the bony nasal ridge have already been freed care must now be taken that the upper lateral cartilages are severed from their insertions at the ridge of the septum In the absence of a hump the necessary intranasal incisions must be made to sever the columella from the free edge of the septum and the upper lateral cartilages from the septal ridge By retracting the columella to one side the nasal spine and the base of the septum are visualized the nasal mucous membrane is elevated with the Joseph elevator from the base of the septum all the way back the same procedure is performed on the other side With a small chisel the septum is separated from its false position on the nasal floor it is forcibly moved into the midline, and the perpendicular plate of the ethmoid bone may now be fractured The insertion and spreading of a septal speculum is helpful in manipulating and freeing the septum The septum may then remain in the midline without a return of the deviation

Where the lower free border of the septum is laterally displaced and causes protrusion of it into one nostril obstruction of the other nostril at the site of the angulation and drooping of the nasal tip the following procedure is added From the previously mentioned incision through the

Immobilization If after correction of the deviation, there is no tendency of the fragments to return to their former position, the nasal packings are replaced with packings of petrolatum gauze and the following simple immobilization applied (Fig. 200) A medium-sized cork is halved longitudinally The flat side is placed upon the formerly deflected nasal side and held firmly in this position with adhesive strips, which also pull the nose toward the corrected side Packings and immobilization device are removed after forty-eight hours, and the nasal vaults are cleansed with applicators dipped in hydrogen peroxide solution The immobilization device is reapplied and worn for another week

If after correction of the deviation there is a tendency for the deviation to recur, an adjustable nasal splint should be worn for several weeks. Blair's wire anchorage is recommended (Fig 201) From a small incision over the lateral aspect of the nasal bone of the deflected side, a small hole is drilled through the bone near its free border, and the ends of a loop of thin stainless-steel wire—slack end armed with a strong straight needle—are passed through the hole and around the free end of the bone, then obliquely through the septum and the mucogingival sulcus of the opposite side, where they are fastened to a wire loop applied to a molar or premolar tooth, under sufficient tension Obviously, the nasal packing must be removed before the wire is passed The small skin incision does not require suturing The wire should remain in place for four weeks

RETRUSION OF MIDFACE (DISHFACE DEFORMITY)

Under this term are combined certain congenital or traumatic deformities in which a retroposition of nose and middle of the face is characteristic, but which, in the final analysis, vary a great deal For this reason, the treatment or variety of treatments must be adapted to each case In general, the deformity may be classified as follows.

Group 1: A typical situation is the retrusion of the upper lip in certain cases of secondary cleft lip and palate deformities, with a short, hanging columella, marked diminution of the columella-lip angle, and a drooping nasal tip The retrusion of the upper lip is due either to faulty technic of primary lip repair or to lack of maxillary development after cleft-palate operation (see p 249) The nasal deformities are usually due to lateral displacement of the septum, depriving the nasal tip and columella of support

Group 2: To this group belong certain traumatic or more often congenital dishface deformities in which the entire midface is flattened, including the nose, and the columella is drooping over the recessed upper lip, producing a sunken-in impression Often, the lower part of the

the columella. The reflected mucous-membrane flaps are reduced to proper side and the wounds sutured.

Where the displacement of the lower end of the septum is associated with a long nose Brown and McDowell advise cutting off the crooked lower end of the septum chiseling off any deforming sector of the nasal spine and shortening the nose (see p 319)

Fig. 201: Wire anchorage of severed nose (after Blair)

After the deviation is corrected there may still exist a partial obstruction of the airways this can be overcome later on after healing is complete with a submucous resection

cartilage graft should be fastened either with a pin (p 331) or by applying a cork-splint, as described on p 338, to prevent slipping

If there is a coexisting protrusion of the mandible, it should be overcome by reduction of the protruding anterior bony part of the mandible (from an incision behind the chin), unless there is malocclusion of the teeth If this is the case, the mandible must be set back, as described on p 438

FRACTURES OF NOSE

For treatment of nasal fractures, the reader is referred to p 436

RHINOPHYMA

Rhinophyma is, according to the present consensus, a hyperplasia on the basis of acne rosacea (Adequate references have been compiled by Farina) It consists of enlargement of the sebaceous glands, associated with an infiltration of hyperplastic fibrous tissue The nasal tip and the lower nasal ridge are the usual sites of the nodular reddish blue growth Conservative treatment is unsuccessful

Operative treatment consists of paring down the growth to proper nasal proportions without exposing the cartilages or rim of the nostrils, of thorough hemostasis, and of covering the raw surface with a full-thickness graft, from the posterior surface of the ear, or a thick split graft (Case 48, p 912) In some cases, skin-grafting may be omitted in the expectation that epithelium will regenerate from the remnants of the sebaceous glands, the raw surface is simply covered with bismuth tribromophenate (xeroform) gauze Transplantation of a forehead flap is hardly ever indicated

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cartilaginous septum and the nasal spine are found absent. The deformity may be accentuated by an associated protrusion of the mandible (Case 53 p 918)

Group 3 A third group of midface retrusion is due mainly to syphilitic destruction of the nasal bones and cartilages as described on p 331 The treatment of this group is outlined on pp 331–333

Technic: The treatment, as already mentioned must be adapted to each case. In a slightly retruding lip and drooping columella, an incision is made along the upper gingival sulcus and the lip mucosa is advanced from each side toward the midline to make it protrude upon the nasal spine. The drooping of the columella is overcome by shifting a displaced lower septal cartilage into the midline (p 335) or by advancing the columella (p 326) or by transplantation of a strut (p 330) In severe cases in which the retrusion of the upper lip is mainly due to shortness (tightness) (see Cleft Lip Deformities) the lip is lengthened (loosened) with an Estlander flap from the lower lip (p 192) or the Dieffenbach Webster cheek-sliding operation (p 200) The nose is lifted with an L-shaped strut (p 330) In cases of retrusion of the maxilla in which the jaw is edentulous or the front teeth are missing (mainly after accidents) the lip can be advanced by deepening the gingivolabial sulcus with an inlay skin graft (p 280) A prosthesis of acrylic resin or light metal for instance which pushes the lip forward is inserted in this pocket The prosthesis is fastened to a removable upper denture (Case 53 p 918) Any associated nasal deformity can be overcome in the same or a second stage If teeth are present the upper jaw itself is built up with the use of cartilage grafts followed by reconstruction of the nose The insertion of the grafts is best done after the method of Ragnell who prefers bone chip grafts instead of cartilage.

Technic (after Ragnell) A columella split incision is made (p 330) which however should be extended into the upper lip From this incision the nasal ridge is widely undermined and this includes the lateral nasal walls the space between columella and septum is opened Dissection and undermining are continued at the base of the columella over the nasal spine and over the anterior surface of the maxilla behind the ala care must be taken not to perforate the nasal or oral cavities a Joseph periosteal elevator is of great help in this procedure. The entire cavity is now packed with bone chips (p 66) while the soft tissues and the ala should be held elevated By manipulation from the outside and also along the upper gingival sulcus an even surface can be achieved The L-shaped cartilage is then inserted to elevate columella and nasal ridge (p 330) Owing to the wide undermining over the nasal ridge the ridge

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X

THE EYELIDS, EYEBROWS, AND ORBITS

REPARATIVE surgery of the eyelids, eyebrows, and orbits is a part of ophthalmic plastic surgery, and thus belongs to this specialty. The general surgeon, however, confronted with traumatic wounds of the eyelids, must be informed about the proper ways of repair to avoid injurious consequences The general plastic surgeon will find that repair in these regions encroaches upon his field, particularly if he is required to reconstruct regions around the eye as well as neighboring parts of the face.

Defects

DEFECTS OF EYELIDS

Anatomy of Eyelids: The eyelids are composed of two layers, which are combined at their peripheral end by the lid margin (Fig 202) The outer layer consists of skin, musculus orbicularis, lashes and their glands, the inner layer of tarsus, meibomian glands, and conjunctiva The septum orbitale reaches from the periosteum of the orbital rim to the upper border of the tarsus The tarsus is a fibrocartilaginous plate, which gives each lid stability. It is connected with the lateral wall of the orbit and, mediad, with the internal palpebral ligament. It is higher in the upper lid than in the lower lid

The upper lid is lifted by the musculus levator palpebrae superioris, which is innervated by the nervus oculomotorius. The muscle originates in the vicinity of the canalis opticus, extends along the roof of the orbit, and is inserted with a broad tendon to the upper rim of the tarsus A few of its bundles penetrate the septum orbitale and musculus orbicu

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lids should be closed as precisely as possible While closure of horizontal wounds does not offer any difficulties, vertical wounds may involve problems, particularly if the full thickness of the lid is involved If the wound edges are ragged, they should be excised, however, as sparingly as possible If, in vertical wounds, parts of the lid are damaged and must be removed, the defect should, if possible, be made triangular, with the base of the triangle at the lid margin

The wound edges are sutured in layers The first suture, consisting of silk, is passed through the lid margins and approximates them as accurately as possible The suture is not tied, but used as a traction suture If pull is now exerted upon this suture, the corresponding structures will fall in line with each other, and are sutured Conjunctiva and tarsus are approximated with buried sutures of 00000 chromic catgut or cotton in such a way that the sutures are passed through the tarsus only and tied upon it. Then follows suture of the orbicularis muscle (with the same material) and of the skin (with fine silk) Finally, the marginal suture is tied To avoid later notching of the lid margins, Wiener's suggestion is a good one, that is, to give the skin defect an elliptical shape Another good suggestion is to place the two rows of sutures in different planes, what is called in carpentry "halving" (Duverger, Wheeler) (Fig 216, Case 54, p 919) After yellow mercuric oxide ointment is instilled into the conjunctival sac, the wound is dressed with sterile gauze, and an eye pad is applied to both eyes to counteract overmotility The skin sutures are removed on the fourth day, but the marginal suture should remain in place for ten days

Defects of Skin of Eyelids

Defects of the covering skin of an eyelid must be replaced by skin to avoid contractures, unless the defect is of such size as to permit simple closure by suturing The skin defect can be closed either by skin-grafting or by pedicle flaps The skin of the eyelids, however, is so thin that whenever possible they should be replaced by a free graft rather than by a flap

Wheeler has improved the grafting method to such a degree that results have been uniformly good The two features which constitute the improvement are the intermarginal suture with temporary closure of the eyelids—thus splinting and immobilizing the eyelids and protecting the cornea at the same time—and the use of a full-thickness graft from the sound eyelid

Pedicle flaps are much less pliable than grafts and, therefore, less than ideal for replacing the skin of the lid They are, however, of value in

laris to fuse with the skin In addition to the levator there is the smooth muscle of Müller, which is innervated by the sympathetic nerve The musculus orbicularis which is innervated by the nervus facialis closes the lids.

Wounds of Eyelids

The general principles of repair are the same as in wounds elsewhere on the body It should be emphasized however that wounds of the eye

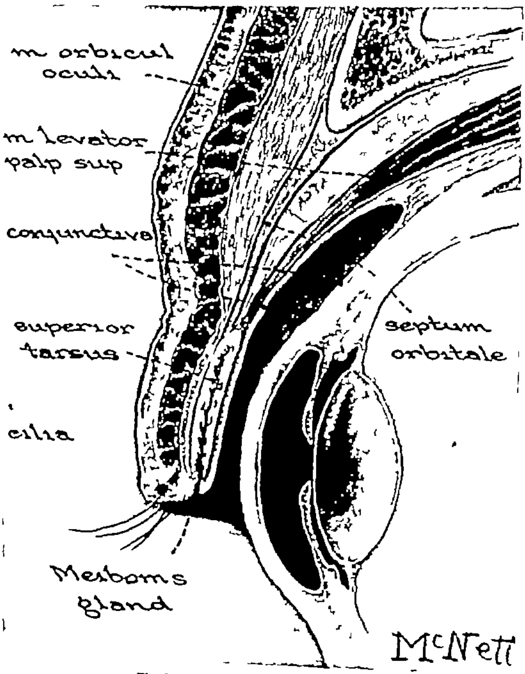


Fig. 202: Anatomy of eyelid (schematic)

relaxed, steps are taken to create intermarginal adhesions With a small pair of scissors, the lid margins of upper and lower lids immediately posterior to the cilia are denuded exactly opposite each other. The small wounds are placed between middle and lateral and middle and median third of the lid margins. Mattress sutures are now passed through small plates of rubber (cut from sterile rubber tubing), overlying the skin of both upper and lower lids near their margins, or the mattress suture is tied over a second black silk suture, lying loose as a seton These sutures are tied snugly, to assure firm apposition of the corresponding raw surfaces. Union of these raw surfaces causes adhesions, which hold the upper and lower lids together

A pattern is now made of the defect The grafts should preferably be taken from the opposite eyelid or from the eyelids of the opposite eye As much as half of the skin can be removed without subsequent impairment of function The pattern is laid upon the donor lid and circumscribed with an incision Four traction sutures are passed through the graft edges opposite each other, and under constant traction and pull at the lid, the graft is removed. The same traction sutures are used to anchor the graft to the defect's edges If the defect is so large as to require more grafts, additional grafts are taken from the posterior surface of the ears If such is the case, the graft from the lid is used to replace the actual lid defect, and the other grafts are used to cover the remaining raw surfaces All grafts are sutured in place If upper and lower lids are involved, a thick split graft, from the hairless median side of arm or thigh (donor areas not to be shaved!), is used for each lid and sutured in place Brown and Cannon consider full-thickness grafts from the neck and supraclavicular region superior because they are soft, provide good function, and have good color match (Case 2, p 846) If these skin areas are too thick, split grafts rather than full-thickness grafts should be used

After-Treatment: A heavily padded pressure dressing is applied for ten days, care being taken to avoid undue pressure upon the eyeball Upon the first change of the dressing, the sutures are removed, with the exception of the mattress sutures, which should remain in place a few days longer to assure firm intermarginal union The intermarginal adhesions are not severed for at least three months to counteract recontracture

The intermarginal adhesion technic is excellent in severe contractures In less severe cases, however, it may not be needed The graft is simply covered with mechanic's waste, and pressure is applied by tying the skin sutures, which have been left long, over the mechanic's waste

those cases of cicatricial ectropion of the lower lid in which the scar is thick and penetrates deep down to the orbital rim A pedicle flap—particularly if anchored to the orbital rim—provides a suitable support and elevation of the lid If possible the flap should be taken from the immediate neighborhood (see p 349) or if the neighborhood is cicatricial from distant parts (Case 57 p 922)

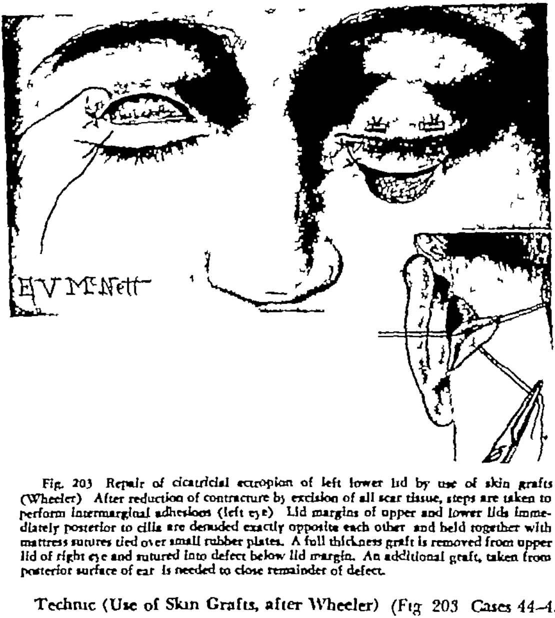


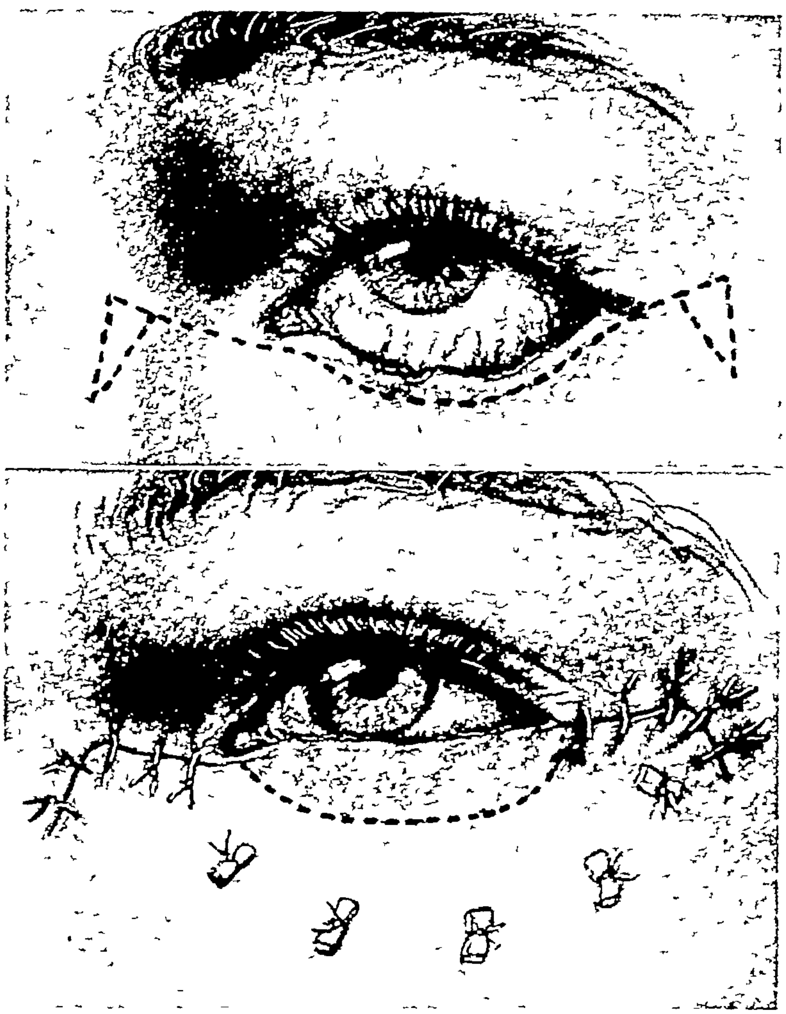
Fig. 203 Repair of cicatricial ectropion of left lower lid by use of skin grafts (Wheeler) After reduction of contracture by excision of all scar tissue, steps are taken to perform intermarginal adhesions (left eye) Lid margins of upper and lower lids immediately posterior to cilia are denuded exactly opposite each other and held together with mattress sutures tied over small rubber plates. A full thickness graft is removed from upper lid of right eye and sutured into defect below lid margin. An additional graft, taken from posterior surface of ear is needed to close remainder of defect.

Technic (Use of Skin Grafts, after Wheeler) (Fig 203 Cases 44–45 pp 920–921) The most suitable example is the correction of cicatricial ectropion The first incision is led parallel to the rim of the distorted eye lid. Two traction sutures are placed through the lid margins and while they are pulled every bit of scar tissue is removed to avoid future recontracture Care should be taken not to injure the orbicularis fibers. Bleeding is stopped by pressure rather than by ligatures If the eyelid is

tiva of the lower, as well as the conjunctiva of the upper, lid should be replaced by mucous-membrane grafts from the buccal mucosa (see p 43) The supporting tissue is provided by ear-cartilage grafts

Although a distinct classification of the full-thickness defects is impossible, owing to their great variety, the author groups them here as follows (1) those involving the marginal parts of the lid, (2) vertical defects,

a



b

Fig 205 Variation of technic of Fig 204, without lower incision Excision of lateral and median triangle of skin to facilitate skin-shifting Mattress sutures through flap anchor latter to orbital rim

(3) defects of the canthal angles, and (4) defects of the entire lid The lower lid is involved more often than the upper.

DEFECTS OF MARGIN OF LOWER LID

Technic (Kuhnt; Modification after Spaeth) (Fig 204) · The principle of this operation is the formation of a sliding bridge flap from the cheek.

Defects of Full Thickness of Eyelids

The full thickness defect may be partial or total It may require replacement of cover and lining or of cover lining, and support. The lining can be replaced by skin grafts or by mucous membrane grafts If the eyeball is still present and intact, the lower palpebral conjunctiva can be replaced by skin but—as Spaeth emphasizes—to avoid approximation of the skin surface of the lid to the contiguous cornea the bulbar conjunc

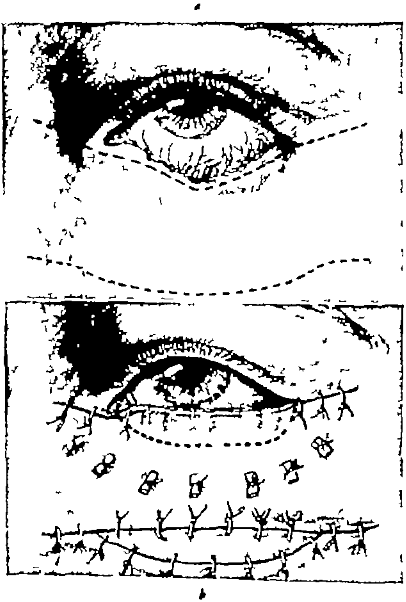


Fig. 204: Repair of defect of lower lid margin (Kuhnt, Spaeth) *a* Outline of bridge flap to be shifted upward into defect. *b* Bridge flap its marginal end one week previously lined with mucous-membrane graft, is anchored in place. Secondary defect below flap is covered with full thickness skin graft mattress sutures through flap anchor latter to orbital rim.

The flap is now moved upward The inferior border of the mucous-membrane graft is sutured to the conjunctival margin of the defect Firm anchorage of the flap follows, with sutures to the periosteum of the inferior orbital rim, with mattress sutures tied on small rolls of gauze, then to the internal canthal ligament, anteriorly and posteriorly, and to the

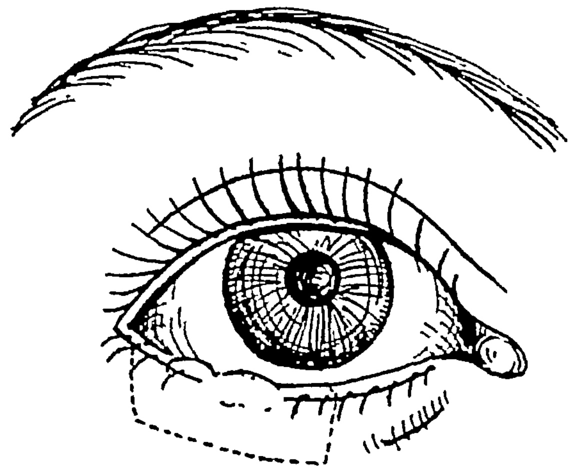


Fig 207 Typical marginal neoplasm The portion of lid indicated by the dotted line is excised through its whole thickness, giving the lesion a margin of 1/4 inch (0 62 cm) on all sides. (Manchester, W M Brit J Plast. Surg)

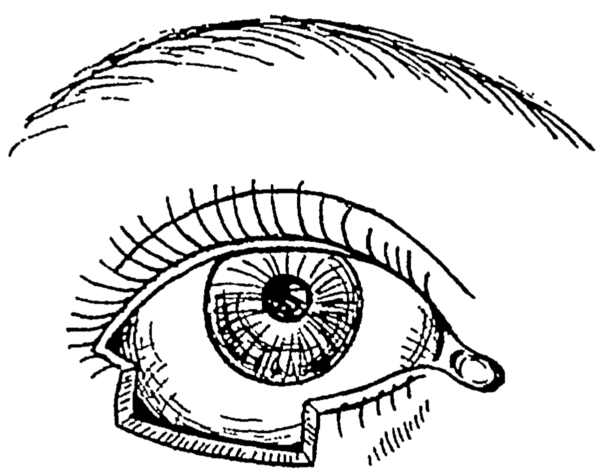


Fig 208 Appearance of partial full-thickness defect requiring repair (Manchester, W M Brit. J Plast Surg)

periosteum of the lacrimal crest; then temporally at the outer rim of the orbit to the periosteum and into the upper lid The secondary defect below the flap is covered with a flap from the immediate neighborhood or with a full-thickness graft from the posterior surface of the ear.

After the flap has well healed in place, a piece of ear cartilage, 5 mm (3/16 inch) wide, is now removed from a posterior incision along the

Step 1 It is first necessary to form a pocket beneath the skin of the lid and to transplant a buccal mucous membrane graft into this pocket at the site of the future new lid margin with its epithelial side toward the conjunctiva The graft is sutured not only to the raw surface of the flap but also to its superior margin

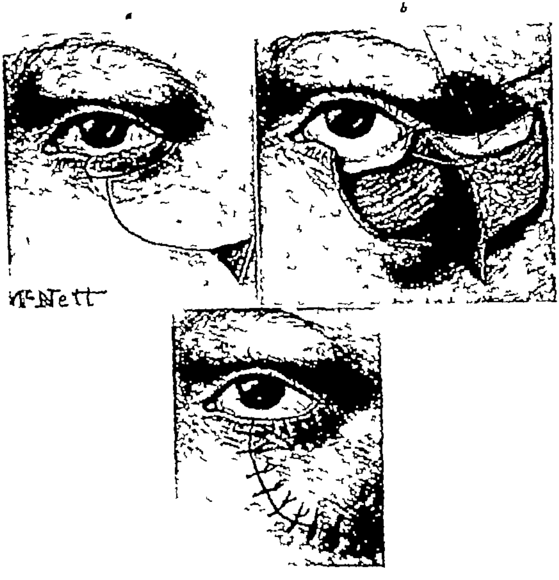


Fig. 206 Excision of carcinoma of lower lid and repair of defect (Imré) Principle of method is rotation of flap from immediate neighborhood. This is made possible by excision of triangle of skin at extremity of curved incision. Margin of flap has been previously lined with buccal-mucous graft. (Compare with Figs. 218 and 219.)

Step 2 After ten days the first incision is lengthened bilaterally temporally and medially for about 2 to 3 cm ($1\frac{3}{16}$ to $1\frac{3}{16}$ inches) upward on a 45-degree angle About 2 to 3 cm below another incision is made parallel to the first incision The ends of this incision—unlike the upper incision—are made horizontal Undermining of the bridge flap follows

side of the triangle nearest the defect curves gracefully over into the line of incision, this allows a greater displacement of the flap toward the defect and a smoother closure The flap is previously lined with a buccal-mucosa graft (see p 43) The incision for the flap is bow-shaped The triangles of skin (after Burow, see p 20) are excised at the end of the incision The narrower the defect, the greater should be the radius of

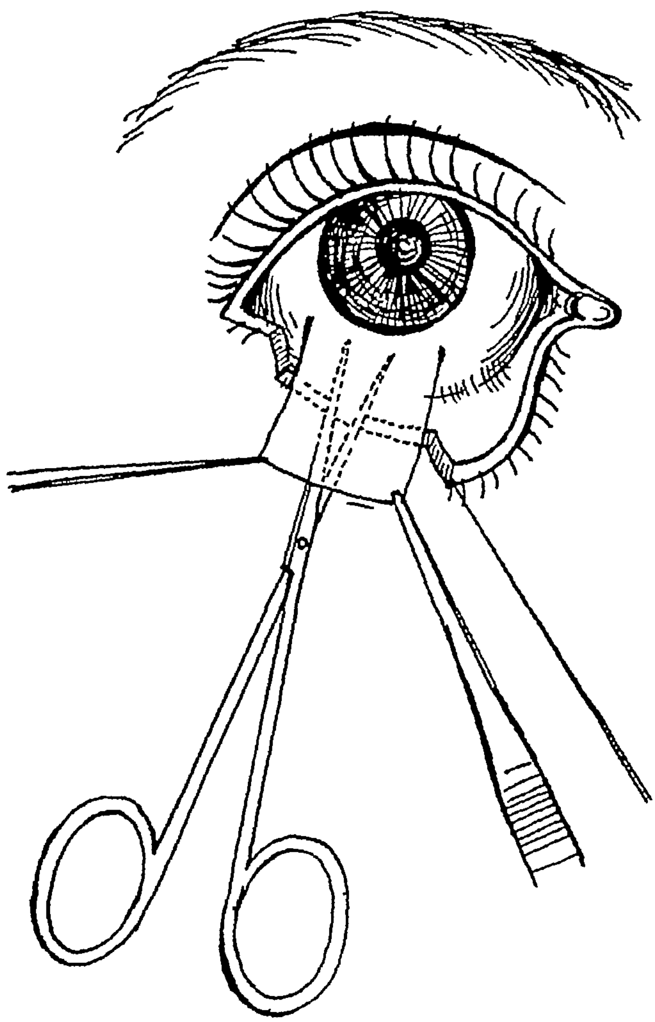


Fig 210 The freeing may have to extend almost to the limbus (Manchester, W M Brit J Plast Surg)

the incision. The flap should be undermined well beyond the incision After its rotation, it is sutured in place with obliquely placed sutures

Manchester introduced a useful technic for closure of partial full-thickness defects of the lower lid In his method, the conjunctiva is replaced by a conjunctival flap from the region of the lower fornix and lower part of the eyeball, and the skin covering is supplied by a double-pedicle flap from the upper lid, as advocated first by Landolt (1885)

concha is thinned and shaped to replace the tarsus of the lower lid and is buried between mucous membrane graft and flap

Variation In narrower defects, one may not need an actual flap but can cover the defect by skin sliding as demonstrated in Fig 205 After the skin is moved upward it is held in this position by suturing it to the inferior orbital rim and by resection of a triangle of skin from the median and lateral borders

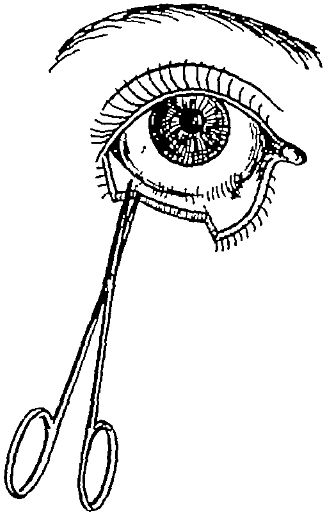


Fig. 209: A conjunctival flap corresponding in width to the defect is freed up from the lower fornix and lower bulbar conjunctiva. (Manchester W M. Brit. J Plast. Surg.)

Technic (Imré) (Fig 206 Case 58 p 923) The principles of this ingenious method are based on the mobilization of a flap from the immediate neighborhood of the defect and sliding the flap into the defect which is made possible by the excision of a triangle of skin at the extremity of the incision. According to Katz, Imré has recently modified his method Instead of an equilateral triangle the apex is rounded and the

Congenital Colobomas· V-shaped colobomas are best repaired by the so-called "halving" method (Duverger, Wheeler). The principle of this method is to overlap the skin and conjunctival wound flaps and to suture them at different planes instead of simple approximation; the latter may be followed by recurrence of the notch.

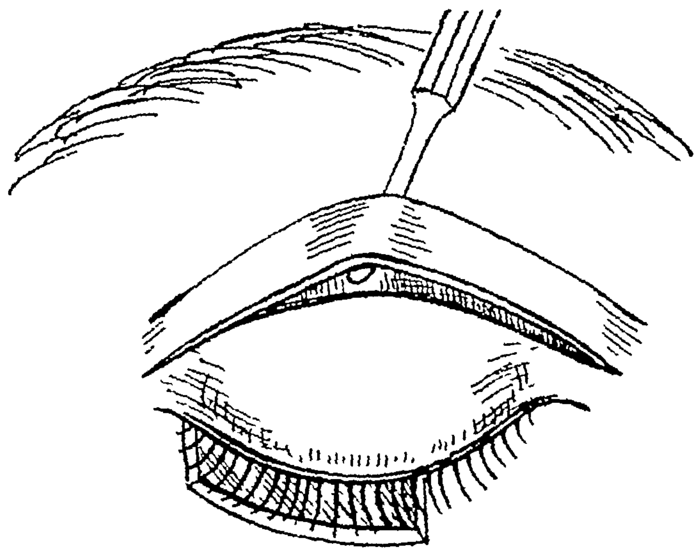


Fig 213 This double pedicle flap is freed (Manchester, W M Brit J Plast Surg)

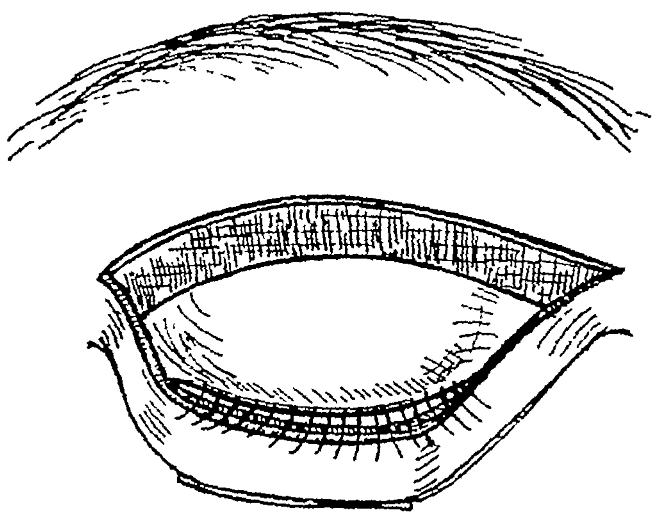


Fig 214 This double flap must lie easily in the defect without tension (Manchester, W M Brit J Plast Surg)

Technic (Fig 216, compare Case 54, p 919) The edges of the colobomas are excised and the skin and orbicularis muscle separated from the tarsus and conjunctival layer To avoid having the sutures for the conjunctiva and tarsus on the same plane as the skin sutures, the following procedure is carried out A small, triangular piece of skin, including lid margin and orbicularis muscle, is excised from one wound edge (the

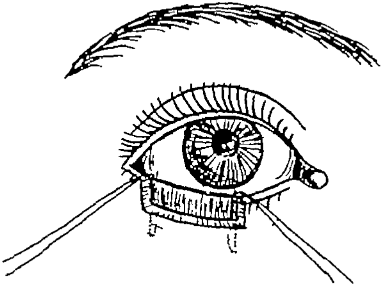


Fig. 211 The flap is folded on itself to recreate the fornix at a slightly higher level than that remaining untouched on either side. It is secured at each corner by a single black silk stitch. If the ends are left long they lie on the cheek and do not irritate the cornea. (Manchester W M. Brit. J Plast. Surg.)

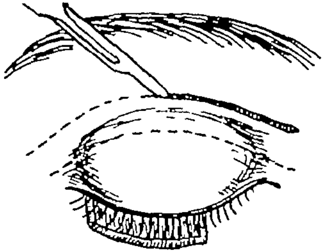


Fig. 212. Closure of the skin defect. A double pedicle flap of the Tripier type is out lined on the upper lid. (Manchester W M. Brit. J Plast. Surg.)

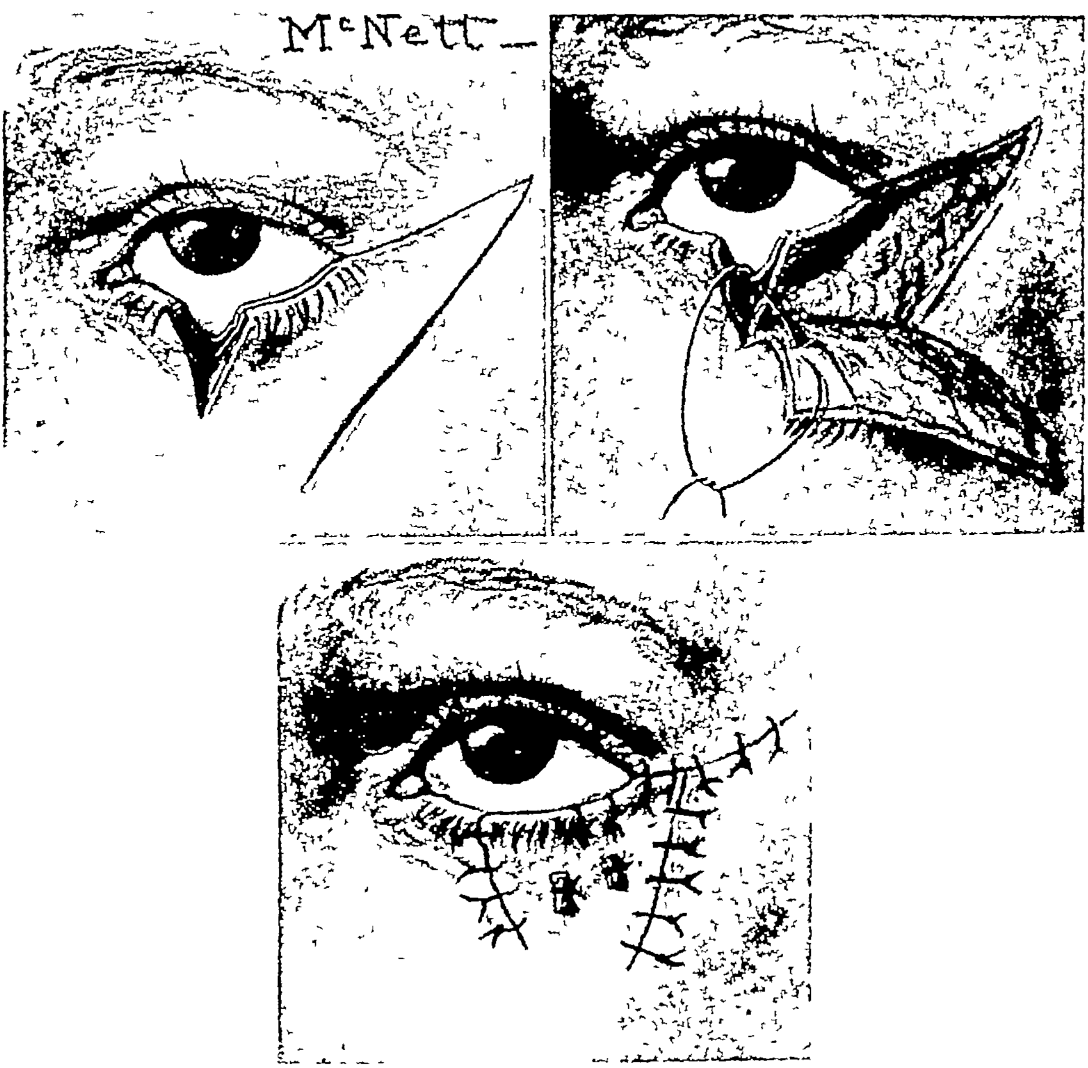
Technic (Manchester) The various operative steps are depicted in Figs 207–215 and are self-explanatory This is the first stage of the operation It is followed two weeks later by a second stage which consists in division of the median and lateral pedicles of the flap and adjustment of flap and pedicles

VERTICAL DEFECTS (COLOBOMAS)

Vertical notches or clefts of the lids, so-called colobomas are con genital or acquired If acquired they are due either to operations (removal of tumors) or to trauma

base of the triangle is at the lid margin), and a similarly shaped piece of conjunctiva and tarsus is removed from the opposite wound edge If the lesion is near the outer canthus, the skin-orbicularis excision should be made from the lateral wound edge, if the lesion is near the inner canthus, it should be made from the median wound edge The conjunctivotarsal layer is sutured first, with buried 00000 catgut or cotton sutures (they should not pass through the posterior surface of the conjunctiva and be tied upon the tarsus) Accurate approximation of the wound edges is necessary. Then follows suture of the orbicularis muscle The skin sutures (fine silk)

a *b*



c

Fig 217, *a* Closure of triangular full-thickness defect of lower lid by rotating square skin flap from lateral portion of lid and temporal region (Dieffenbach, Szymanowski, Kuhnt) Preparatory to formation of flap (one week before transfer), the part of flap which will cover defect is lined *b* Flap is mobilized, lining of flap being sutured to conjunctival defect edges *c*. Flap sutured in place, secondary defect in temporal region closed by starting with closure of lateral corner, mattress sutures tied over small rolls of gauze anchor flap to orbital rim

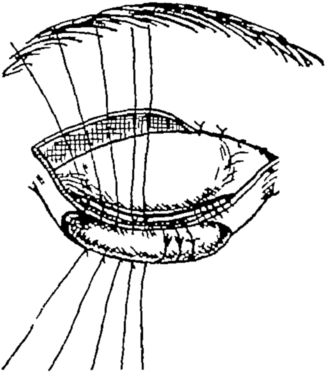


Fig. 215 Two series of stitches are left long to unite the upper border of the skin to the conjunctival flap and the lower border to the remaining eyelid skin, respectively These are tied to each other over a tiny stent mold The upper lid defect is closed with sutures. (Manchester W M: Brit. J Plast. Surg.)

a b

Fig. 216, a V-shaped coloboma repaired by "halving" method (Duverger Wheeler) that is, suturing skin and conjunctiva at different planes. Small triangular piece of skin (including lid margin) and orbicularis muscle is removed from lateral wound edge while similarly shaped piece of conjunctiva and tarsus is removed from median wound edge (dotted line) b Closure of wound in layers.

DEFECTS OF CANTHAL ANGLES

Some of these defects can be conveniently closed by Imré's method (see Figs 218, 219) Other defects may be closed by single-pedicle flaps rotated from the neighborhood Case 60, p 926, demonstrates one example Flaps for the lateral canthal angle may be taken from the temporal or malar region, for the inner canthal angle, from the glabella or nasal region. Either the lining is supplied by local turnover flaps or, as in larger defects, the flap must be lined with a skin graft Delaying the transfer is usually necessary to improve the circulation in these flaps

a *b*

Fig 218 Closure of defect at median canthal angle by Imré's method (See Fig 206)

DEFECTS OF ENTIRE LID

For repair of defects of an entire lid, the pedicle-flap method offers the most versatile form of reconstruction (Fricke, 1829). In some cases, however, where the defect is subtotal—that is, where a small stump of conjunctiva and skin is left—Imré's method, as well as that of Landolt-Dupuy-Dutemp's-Hughes, may have a good chance

Technic (Pedicle Flap): The flap, if possible, should be taken from the neighborhood Only if the latter is cicatricial, a cervical (Case 59, p 924) or arm flap should be chosen The basic forms and locations of flaps from the immediate neighborhood are illustrated in Figs 220, 221 A temporal flap can be used for upper and lower lid, a malar flap for the lower lid, and a frontal flap for the upper lid

The length and form of the flap are determined and outlined according to pattern, to counteract shrinkage, the flap should be made one third larger than required The entire flap is raised. That part of the flap

start at the margin with accurate marginal approximation by leaving the suture long and using it as a traction suture the wound edges fall in line. Thus skin and orbicularis flap overlap the conjunctivotarsal flap If the defect is wide tension on the sutures can be lessened by performing a canthotomy of the external canthal ligament and subcutaneous myotomy of the orbicularis fibers. Dressing and after treatment are as described on p 346

Acquired Surgical Colobomas These colobomas may have various forms In many instances they can be repaired according to Imré s principles (p 353 see also Case 58 p 923 for comparison) The lining is replaced by a buccal mucous membrane graft which is transplanted ten days before the flap is rotated into place, as described on p 349 If the tarsus needs to be replaced a piece of ear cartilage properly shaped and thinned is later buried between the mucous membrane and skin (see p 352–353)

Callahan describes the use of a free composite lid graft (taken from the sound lid) and recommends it particularly for colobomas of the upper lid This is an ingenious but daring method Manchester s technic (p 355) may also be applicable

Technic (Kuhnt after Dieffenbach-Szymanowski) (Fig 217) (Case 57, p 922) In triangular defects this method is a good one The principle is closure of a triangular defect with a square flap rotated from the immediate neighborhood (see Fig 15) The flap consists of the lateral portion of the skin of the lid—leaving the orbicularis tarsus and conjunctival portions in situ—and of the bordering temporal region The temporal incision starting from the outer canthus should be led obliquely upward This not only elevates and supports the lid but also facilitates closure of the secondary defect (see Fig 15) Preparatory to the formation of the flap however (ten days previously) a buccal mucous-membrane graft of the size of the conjunctival defect is buried beneath the posterior surface of that part of the flap which is to cover the defect (see p 43) A piece of ear cartilage to replace the tarsal defect is later buried between mucous membrane and flap (see pp 352–353) If the flap is shifted into the defect, the graft of the mucous membrane will form the posterior surface of the lid

If neither Imré s nor Dieffenbach s method is suitable for closing partial full thickness defects of the lids temporal cheek or forehead flaps—similar to those used for replacement of entire lids (see below)—may be transplanted.

Acquired Traumatic Colobomas Traumatic colobomas have already been discussed (see above see also Fig 216 Case 54 p 919)

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which is to replace the conjunctiva is lined with a buccal mucous-membrane graft if the eyeball is intact with a skin graft if the eyeball is absent (see p 349) The flap is now returned to its original site and is covered with a pressure dressing Two weeks later, the flap is raised again and a piece of ear cartilage 5 mm (3/16 inch) wide properly shaped and thinned to replace the tarsus is buried beneath the lining of the flap (see p 352–353) The flap is now rotated into the defect. The

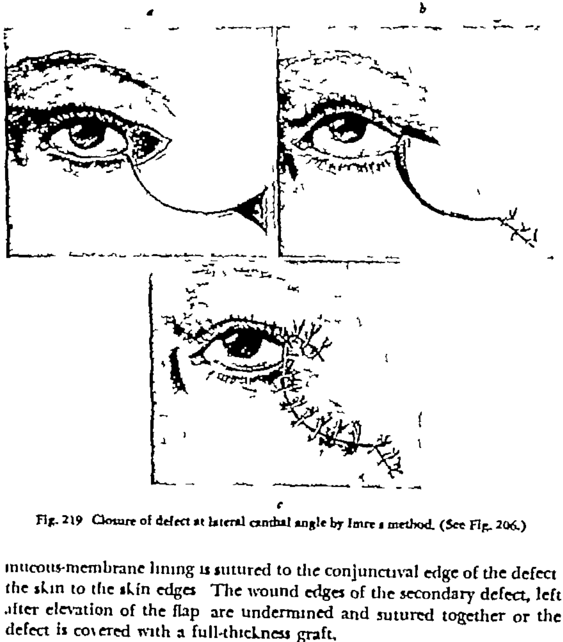


Fig. 219 Closure of defect at lateral canthal angle by Imre s method. (See Fig. 206.)

mucous-membrane lining is sutured to the conjunctival edge of the defect the skin to the skin edges The wound edges of the secondary defect, left after elevation of the flap are undermined and sutured together or the defect is covered with a full-thickness graft.

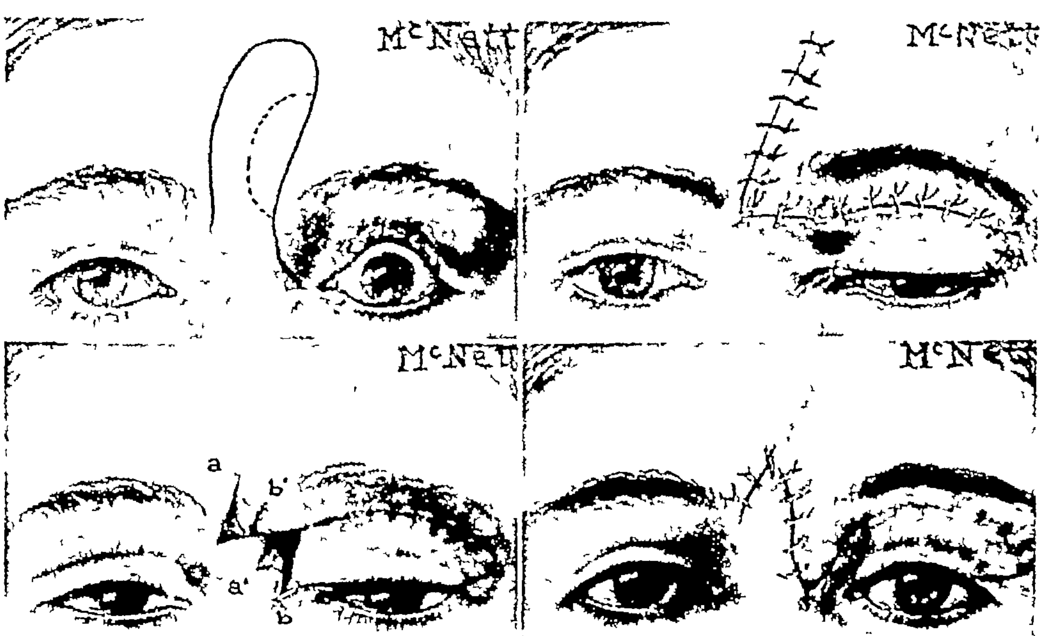
After eight weeks the pedicle of the flap is severed and returned to its original site and flap and pedicle are adjusted in place

After the edema of the flap has subsided the fold of the upper lid

a b

Fig 220, *a* Excision of entire lower lid Malar flap to replace lower lid is outlined Flap is made one third larger than required Flap is raised and lined with buccal mucous-membrane graft to replace conjunctiva (dotted line) and returned to its original site. *b* Two weeks later, flap is raised again and rotated into defect Closure of secondary defect by undermining wound edges and skin-sliding

a b



c d

Fig 221, *a* Replacement of entire upper lid with frontal flap (Wiener) Flap is made one third larger than required It is raised and lined with buccal mucous-membrane graft to replace conjunctiva (dotted line)

b After two weeks, flap is raised again and rotated into defect Raw area of flap bed is closed by undermining wound edges and skin-sliding

c After two months, pedicle of flap is severed and adjusted as in Z-operation (see Fig 53) formation of two triangular flaps, which are made so that their outlines form a Z. They are raised and exchanged so that *a* is approximated to *a'* and *b* to *b'*.

d After Z-operation

which is to replace the conjunctiva is lined with a buccal mucous-membrane graft if the eyeball is intact with a skin graft if the eyeball is absent (see p 349) The flap is now returned to its original site and is covered with a pressure dressing Two weeks later the flap is raised again and a piece of ear cartilage 5 mm (3/10 inch) wide properly shaped and thinned to replace the tarsus is buried beneath the lining of the flap (see p 352–353) The flap is now rotated into the defect. The

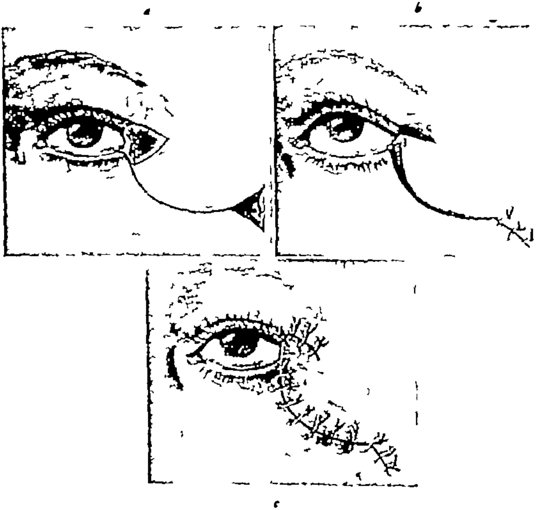


Fig. 219 Closure of defect at lateral canthal angle by Imre s method. (See Fig. 206.)

mucous membrane lining is sutured to the conjunctival edge of the defect the skin to the skin edges. The wound edges of the secondary defect, left after elevation of the flap are undermined and sutured together or the defect is covered with a full thickness graft.

After eight weeks the pedicle of the flap is severed and returned to its original site, and flap and pedicle are adjusted in place

After the edema of the flap has subsided the fold of the upper lid

may be reconstructed by making an incision along the site of the fold and excising some of the subcutaneous tissue so that the resulting scar will become depressed.

Technic (Imré): The basic features and principles of Imré's method have been discussed on p 353 This method is suitable only for subtotal defects of the lower lid where a stump of conjunctiva and skin is still left Lining and support are provided as outlined on pp 349, 352–353

METHOD OF LANDOLT-DUPUY-DUTEMPS-HUGHES In cases of subtotal defects of the lids where a stump of conjunctiva and skin is still left, an ingenious method was devised by Landolt (1881) and improved by Dupuy-Dutemps (1927) and by Hughes (1937)

Technic (Hughes) (Fig 222) The following procedure is for defects of the lower lid, the upper lid can be rebuilt similarly.

Stage 1 From an incision along the intermarginal white line of the upper lid (see p 374), the upper lid is divided into two layers, the conjunctivotarsal layer and the skin-orbicularis lamella The separation is carried upward to about 3 mm ($\frac{1}{8}$ inch) above the margin of the tarsus The skin of the cheek bordering the defect of the lower lid is undermined sufficiently so that it can be pulled upward, without tension, to the level normally occupied by the lower lid The lower epithelial border of the upper tarsus is cut off, and the conjunctivotarsal layer is pulled downward It is sutured to the conjunctival stump of the lower-lid defect with No 36 stainless-steel wire in a continuous running suture, which can be pulled at either canthus A second layer of reinforcing sutures (00000 chromic catgut) is laid over the first suture The previously undermined skin is drawn upward and attached to the anterior surface of the lower half of the tarsus by means of three black silk sutures, which are tied upon rolls of gauze The superficial layer of the upper lid is then attached to the anterior surface of the upper half of the tarsus in the same manner The two skin edges (lid margin and lower skin edge) are sutured together

Stage 2 After an interval of from four to six weeks, the eyelashes of the lower lid may be replaced if this seems desirable (for technic, see below) The hairbearing full-thickness graft is placed in a bed prepared just below and parallel to the margin of the upper lid

Stage 3 From five to seven weeks later, an incision is made transversely, with a pair of blunt-nosed scissors, between the two rows of lashes through the full thickness of the lid Whether the second stage is desirable or not, it is advisable to wait about three months before performing the third stage to allow the structures to stretch sufficiently.

A definite drawback of Hughes' method arises in cases where the lower

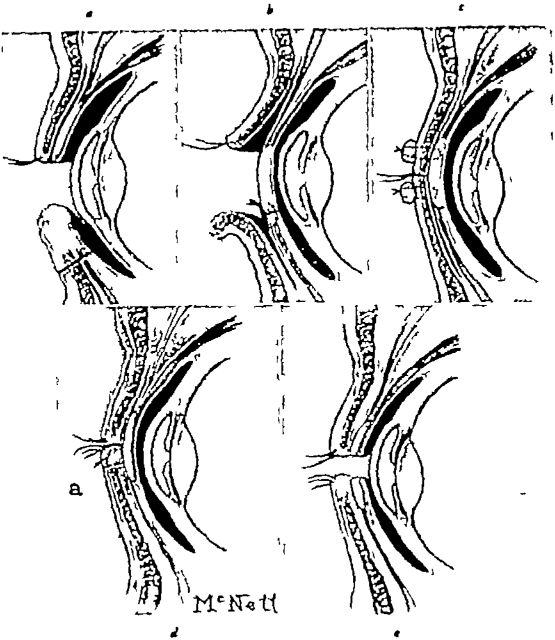


Fig. 222, *a*: Replacement of subtotal defect of lower lid (Hughes) Lower border of defect is marked by heavy horizontal line. Vertical lines indicate level of separation of lower lid and of upper lid.

b: Conjunctivotarsal layer of upper lid is severed from orbicularis skin lamella and brought downward and sutured to conjunctival stump of lower lid. Skin of lower lid stump is mobilized into cheek.

c: Mobilized lower skin is drawn upward and attached to anterior surface of lower half of tarsus with mattress sutures tied upon rolls of gauze. Skin orbicularis layer of upper lid is attached to upper half of tarsus.

d. Second Stage Replacement of eyelashes of lower lid by hair-bearing full-thickness graft (*a*) (see Fig. 224)

e Third Stage: Lids are severed between two rows of eyelashes with transverse incision through tarsus and conjunctiva.

Stage 2: From three to six weeks later, the scar running between upper-lid margin and skin edge of lower lid is incised, and the skin of the upper lid is dissected free and pulled upward until its margin is at the normal level A flap is now taken from above the upper lid, pedicled at the temporal side, rotated into the lower defect, and sutured into place, then follow approximation of the upper-lid margin to the upper margin of the flap and closure of the donor site at the upper lid

Stage 3 From three to six weeks later, the full thickness of the lid is severed along the margin of the upper lid, as described previously

This method (Dupuy-Dutemps) can be facilitated by raising the upper-lid flap in stages before the first stage of the operation so that it can be transferred at the first stage, thus eliminating a second-stage operation Or, better, one may return to the originator's (Landolt's) advice and shift a double-pedicle flap from the upper lid to provide skin cover for the lower lid (see Figs 213–215) Such a flap is well vascularized, and does not need delaying Before it is transplanted, the eyelash margin of the skin of the upper lid is sewn to the tarsus of the upper lid at such a level that not more than the inferior one half of the tarsal plate is exposed The flap is then shifted downward and sutured to the lower-lid margin as well as to the lid margin of the upper lid

W B Macomber and coworkers provide skin coverage with a full-thickness (postauricular or clavicular) skin graft In a second-stage operation, they provide eyelashes for the lower lid by means of a narrow single-pedicled flap (pedicled at the median canthus) that contains along its upper margin a single row of hair follicles from the eyebrow, it is raised in stages

Manchester's method of developing a conjunctival flap (Figs 209–211), appears to be another improvement in this principle of lid reconstruction The conjunctiva is freed from the depths of the fornix and the lower part of the globe from canthus to canthus The flap, corresponding to the entire width of the fissure, is folded upon itself and the fornix re-created The remaining steps are the same as described above

DEFECTS OF EYELASHES AND EYEBROWS

Defects of eyelashes and eyebrows are best replaced by free transplantation of hairbearing full-thickness grafts (Knapp, Lexer, Danternelle, Passot).

Technic (Replacement of Eyelashes): An incision is made slightly distal and parallel to the lid margin, and the wound edges are held separated by traction sutures The graft bed is prepared by enlarging the incision A hairbearing full-thickness graft, 2 mm ($\frac{3}{32}$ inch) wide,

skin (cheek) flap cannot be formed of sufficient width and mobility It may later retract and shorten the new lower lid, and may even cause ectropion The originator of this principle of eyelid reconstruction (Landolt) and his followers (Tripier Dupuy Dutemps) apparently were

a b

c

Fig. 223, *a*. Replacement of subtotal defect of lower lid (Dupuy-Dutemps) (compare also with Fig 222) Conjunctivotarsal layer of upper lid is separated from orbicularis skin lamella and pulled downward and sutured to conjunctival stump of lower lid.

b: Skin orbicularis layer of upper lid is sutured to skin bordering lower lid defect. Flap above upper lid to replace skin of lower lid is outlined (see *c*) Raising it in stages is advisable to assure sufficient circulation.

c: In second stage, skin orbicularis of upper lid is severed along former line of suture, and moved upward. Flap previously prepared above upper lid is rotated into lower-lid defect, and sutured to wound edges of lower lid as well as to margin of upper lid. Raw surface of flap bed is closed by skin-sliding. In third stage, full thickness of lids is severed between margin of upper lid and upper edge of flap (compare also with Fig. 222, *e*)

aware of this fact, and suggested replacement of the lower lid with flaps from the upper lid.

Technic (Dupuy Dutemps) (Fig 223) *Stage 1* Separation of the two upper lid layers and suturing of the conjunctivotarsal layer to the conjunctival stump of the lower lid are performed as just described. The edge of the margin of the upper lid is now sutured to the raw edge of the skin bordering the lower lid defect.

(xeroform) ointment, no other dressing is required As a rule, the hair starts to grow after three weeks, and has to be clipped regularly from then on If the graft fails to take, the procedure should be repeated

W B Macomber et al replace the eyelashes by means of a narrow single-pedicle flap (pedicled at the median canthus) which contains along its upper margin a single row of hair from the eyebrow, the flap is raised in stages

Technic (Replacement of Eyebrows) (Fig 224)· The technic is similar to that used for replacement of eyelashes The graft bed is prepared by excision of a wedge-shaped piece of skin of desired width The graft is removed from the hairline posterior to the mastoid process, as described in the foregoing paragraph The graft should be slightly larger than the defect and cut so that the hair will grow in the proper direction After thorough hemostasis, the wound edges of the graft bed are held retracted The graft is inserted and held in place by mattress sutures, which are inserted through the wound edges of the host area but not through the graft Or simple single sutures are laid through graft and skin edges and left long Mechanic's waste is then laid over the graft, the sutures are tied over it, thus providing uniform pressure The donor area is closed by simple suturing

Variation If the eyebrow of the other side is preserved and sufficiently wide, the lower half of it can be excised and used as a hairbearing full-thickness graft The donor area is closed by simple suturing In some cases, it may also be possible to utilize Monk's arterial island flap (p 73) to provide a hairbearing flap from the temporal region

DEFECTS OF ORBITS

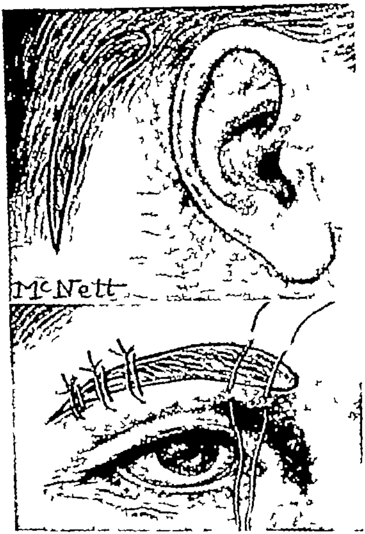
Contracted Socket

The reconstruction of a socket for retention of an artificial eye becomes necessary after enucleation of the eyeball and subsequent obliteration of the socket through adhesions between lids and underlying structures Many methods of reconstruction have been devised The use of a free skin graft wrapped around a stent (Esser, Gillies, Killner, Wheeler, and others) has given most satisfactory results. Wheeler has contributed much towards the standardization of the method

Technic (Fig 225) An incision is made between the margins of the eyelids, the margins are held apart by traction sutures, external canthotomy is now performed by pushing one blade of a pair of straight scissors into the lateral cul-de-sac—the lids are held apart and pushed toward the nose with thumb and index finger of the right hand—and closing the other blade down on the skin; the tissues are severed with one snip

is taken from the hairline posterior to the mastoid process where the hairs are not so strong as elsewhere on the scalp Since the hair penetrates the scalp obliquely the knife should be led in the same direction so as not to destroy the hair follicles The graft consists of the full

a



b

Fig. 224 Replacement of eyebrow with hair-bearing full thickness graft from neck hairline posterior to mastoid process. *Graft is held in place with mattress sutures, which* are inserted through wound edges of recipient area but not through graft. Mechanic's waste can be placed beneath the sutures and the latter tied over it to provide uniform pressure

thickness of the skin and some fat tissue With a pair of scissors, the fat tissue is then trimmed away until all hair roots are exposed but the latter should not be injured It is inserted into the wound bed and anchored in place by sutures similar to those used in grafting eyebrows (Fig 224) The grafted area is covered with bismuth tribromophenate

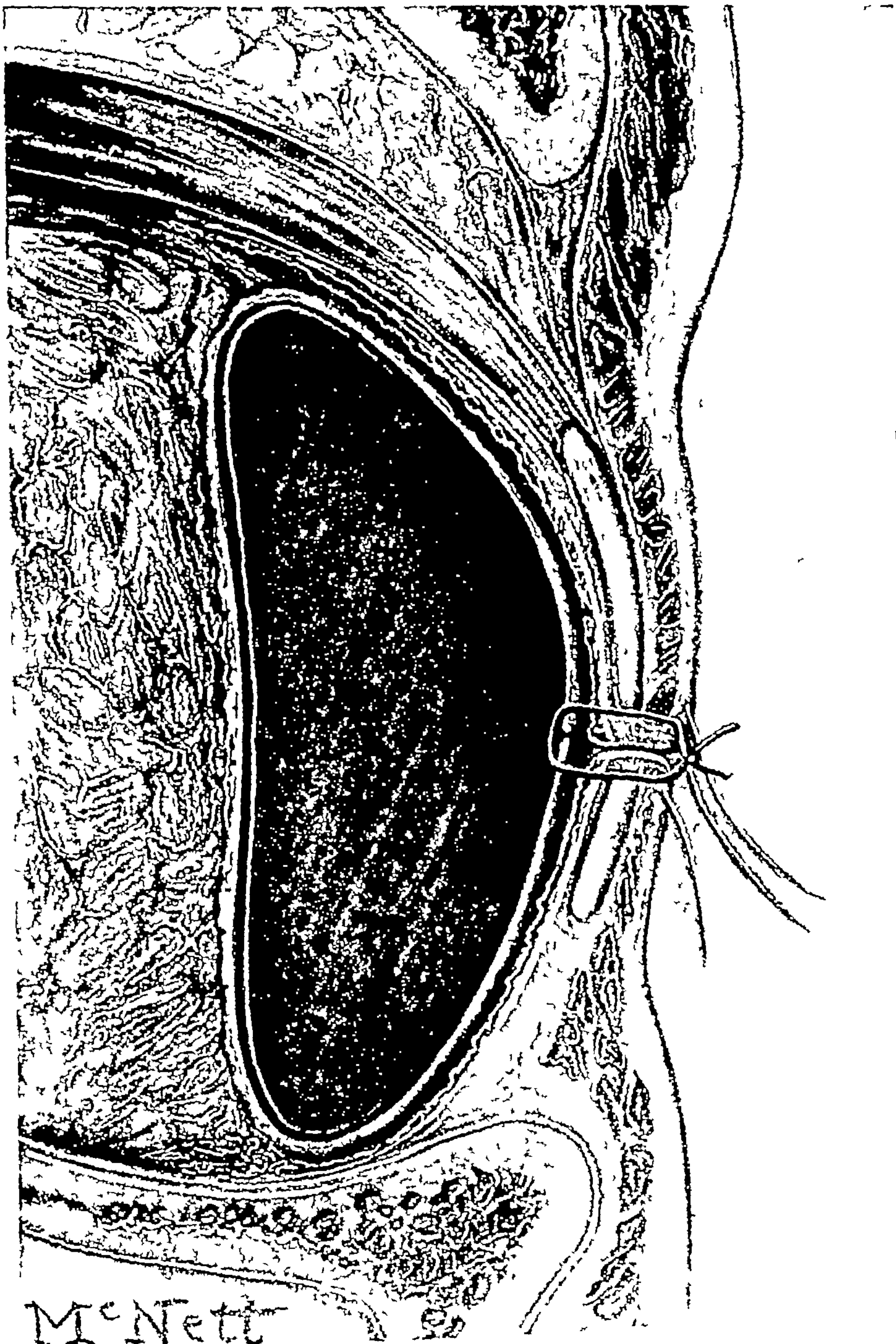


Fig 225 Reconstruction of contracted socket. Lids are dissected away from underlying scar tissue Plane of dissection is posterior surface of tarsus Inferiorly, dissection is carried to periosteum of orbital margin Superiorly, dissection is carried behind orbital rim Bony rim of orbit should not be touched so that orbicularis and levator palpebrae muscles can be saved Mold of dental compound is made of cavity Split skin graft is wrapped around stent, raw surface outward (graft is indicated by white line around mold) Graft should be arranged in such a way that its overlap presents at palpebral fissure Mold and graft are inserted and immobilized by suturing lids together in such a way that each suture includes part of overlap of graft.

This facilitates introduction of the stent, since the sac is larger than the palpebral fissure The lids are now dissected away from the underlying scar tissue The dissection must be kept superficial on a plane along the tarsus of the lids so that only the lids proper are freed and no scar tissue is left on the posterior surface of the lids Temporally and below the dissection should be carried well to the orbital margin so that the graft will adhere to the periosteum of the anterior aspect of the orbital margin Superiorly the dissection is carried behind the orbital rim the bony rim of the orbit however should not be touched so that the musculus orbicularis oculi and musculus levator palpebrae superioris can be saved On the nasal side, the dissection is carried posterior to the plane of the normal caruncle and to the anterior crest of the lacrimal groove and the orbital rim above it. All scar tissue is removed from the cavity The next step is thorough hemostasis obtained by packing the cavity with moist gauze.

A mold of dental compound is now prepared. It is softened in hot water and introduced into the cavity The dimensions of the mold are approximately: length 3 to 4 cm ($1\frac{3}{16}$ to $1\frac{9}{16}$ inches) width 2.5 cm (1 inch) thickness, 1 cm ($\frac{3}{8}$ inch) While still soft, the mold is shaped to fit the cavity and left in place until it hardens. It is then removed Upon the anterior surface of the mold a point corresponding to the median or lateral canthal angle is marked out by scratching the mold with a knife This will facilitate correct reinsertion Rough points are smoothed down with the knife. A split skin graft is removed from the hairless region of upper arm or thigh (donor area not to be shaved preoperatively!) and wrapped around the mold raw surface outward as described on p 37 The graft should be arranged in such a way that its overlap is at the palpebral fissure Mold and graft are now inserted and immobilized by suturing the lids together in such a way that each suture includes a part of the overlap of the graft In cases of contracted socket in which there is sufficient conjunctiva to be worth conserving the graft should consist of buccal mucous-membrane and not of skin since a combination of skin and mucous membrane has proved unsatisfactory If not enough conjunctiva is present it should be removed and the entire graft be made of split skin

After Treatment Bismuth tribromophenate (xeroform) gauze is placed upon the lids and a proper pressure dressing applied Both eyes should be included The dressing is changed after one week but the mold is left in place for three weeks Three weeks after the operation the sutures are removed the mold lifted out and the canthotomy wound closed with sutures. An artificial eye may now be introduced If a

be removed, the cavity is closed with a flap from the forehead (of proper size and shape, pedicled at the root of the nose, and containing the arteria supraorbitalis and arteria frontalis) or a flap from the temporal region (containing the anterior branch of the arteria temporalis) should be mobilized and rotated into the defect. The flap is sutured to the wound edges of the skin along the orbital rim. The secondary defect at the donor site is covered with a full-thickness graft. The pedicle of the flap is partly severed after three weeks. Final separation and adjustment of flap and pedicle are completed after four weeks.

Extension of Malignancy into Orbit. In cases where a malignant tumor of the maxilla or of frontal or other sinuses has broken into the orbit necessitating removal not only of the orbital contents but also of parts of the orbital wall, a large cavity is created, which has a broad communication with the oral and nasal cavities. This cavity should not be closed primarily for two reasons: to prevent ascending infection of the sinuses and to prevent overlooking possible recurrences. Only if a sufficient interval, preferably five years, has elapsed without evidence of recurrence and active infection is controlled should closure be attempted. In the meantime, the patient is treated conservatively and infection controlled by cleansing the cavity with irrigation and application of local antiseptics. If possible, the cavity is temporarily closed with a latex or other type of prosthesis for cosmetic and functional purposes. The prosthesis may be simple or more elaborate, fixed to a pair of glasses, forming an upper and lower lid and holding an artificial eye. Final closure of the cavity is achieved by transplantation of a lined flap either from the forehead (Case 61, p. 927) or from distant parts.

Bony Defects of Orbit

Bony defects of the orbit may need repair for functional or cosmetic reasons. Defects of the upper rim are less likely to be followed by functional disturbances, but may cause deformities for which the patient seeks plastic repair. Defects of the lower rim from old depressed fractures of the floor of the orbit or the malar bone, for instance, may cause a more or less marked ptosis of the eyeball with subsequent functional disturbance.

Technic: Bony defects of the entire upper rim are best repaired with cartilage grafts. The incision runs just within the eyebrow, which should not be shaved but held covered throughout the operation. The incision penetrates through the soft tissue and the periosteum down to the bone. The periosteum is mobilized over the deformity to form a pocket into which an autogenous-rib-cartilage graft is inserted (p. 58). The graft may be carved according to a pattern, which can readily be obtained with

matched ocular prosthesis is not available at this time, the mold must be reinserted.

Exenteration of Orbit and Repair

Exenteration of the orbital contents becomes necessary if malignant tumors infiltrate from the eyelids the eyeball the maxilla or the sinuses into the orbit. In some cases, the eyelids must be removed at the time of the exenteration in other cases they can be spared wholly or at least their skin covering

Technic. *Conservation of Full Thickness of Lids, Including Conjunctival Lining* If the full thickness of the eyelids, including their conjunctival lining can be spared the incision starts with separation of the fornices of the upper and lower cul-de-sacs. The periosteum of the orbital rims is now incised and elevated together with the orbital contents, and it is freed from the orbital wall until the apex is reached Pressure against the bone should be avoided to prevent perforation of the bony wall which in some places is quite thin After mobilization of the orbital contents the entire mass is removed from its pedicle at the apex bleeding from the arteria ophthalmica can—as a rule—be arrested by pressure. To prevent necrosis of the bare bone covering of the bone becomes necessary For this purpose the conjunctiva of the upper and lower fornices is dissected free and stretched until it can be pushed into the depth of the orbit and held in place by packing (Spaeth) Or it may be possible to suture the mobilized conjunctiva of upper and lower fornices transversely together as it is done after enucleation of the eyeball (Axenfeld)

Sacrifice of Conjunctiva of Lids If the conjunctiva of the eyelids cannot be spared but must be removed together with the orbital contents, the incision starts at the lid margins after the margin is penetrated, tarsus and conjunctiva are separated from the lids until the upper and lower cul-de-sacs are reached the dissection from then on is the same as described in the foregoing To cover the naked bony wall the lids—after removal of their margins—are pushed with their denuded posterior surface into the depth of the orbit and held in place by packing If not all the bone can be covered in this way, it is left to granulate.

Sacrifice of Full Thickness of Lids If the lids in their entire thickness must be sacrificed the incision starts along the orbital rim and penetrates down to the bone Lids and conjunctival sac are now removed, together with the orbital contents, as previously described If the periosteum of the orbital bones can be left attached to them an inlay skin graft can be used for coverage (Case 62 p 928) If the periosteum must

د

a mold of dental compound pressed into the defect. The graft is held in place with thin stainless-steel wires inserted through drill holes in graft and host bone In partial defects of the upper rim diced cartilage grafts (p 59), dermal fat grafts (p 45 Case 12 p 861) or dermal grafts (p 42) can be used to good advantage.

In defects of the lower rim of the orbit with ptosis of the eyeball an incision is made immediately below the eyelashes (Converse and Smith) The fibers of the orbicularis oculi muscle are split and the anterior portion of the depressed orbital floor is exposed. The periosteum is elevated from the latter and from the floor of the orbit until the orbital contents can be raised sufficiently A wedge-shaped graft of cartilage—with its base outward—is now driven into the subperiosteal pocket and held in place with sutures Then follows closure of the skin incision

Deformities

ECTROPION

Ectropion is a condition in which the eyelid is rolled outward so that the conjunctiva either partly or wholly is visible and exposed to the outside. It may affect one lid or both It is either cicatricial or noncicatricial Of the latter the paralytic or senile form represents the majority of cases and constitutes a relaxation of the skin and muscles involving the lower lid only

Cicatricial Ectropion

The repair of this condition has been described on p 347

Paralytic or Senile Ectropion

Paralytic or senile ectropion may be partial involving only the lid margin or may be complete The type of repair depends upon the extent of the condition

Technic (Partial Paralytic Ectropion) (Ziegler) This is a simple and effective procedure consisting in galvanopuncture of the conjunctiva and tarsus with the purposes of producing a scar which will cause contracture and thus elevation of the lid The procedure can be done *in* the ambulant patient The lid is everted and after an instillation of 1 per cent solution of tetracaine hydrochloride (pontocaine) procaine is injected beneath the conjunctiva A blunt pointed galvanocaustic electrode heated to redness or an electrocoagulation needle is quickly pushed drawn at points 3 mm. (1/8 inch) apart along a line *5 mm* (3/16 inch) away from and parallel to the lid margin. Yellow mercuric oxide oint

the other side in the same sitting if it needs correction The dressing is removed after four days, the sutures after from five to seven days

Technic (after Fuchs for Paralytic Ectropion after Facial-Nerve Palsy) (Fig 227) The extent to which it is desired to bring the lids together is marked out The lower lid is now split to the same extent in the marginal incision This is the gray line that separates the orifices of the meibomian glands from the roots of the cilia The lid is now split within the loose connective tissue that separates the tarsus and the muscular fibers of the orbicularis The lid is split into two lamina—the anterior consisting of skin with the cilia, and the posterior, the tarsus

a *b*

Fig 227, *a* Repair of paralytic ectropion after facial nerve palsy (Fuchs) Extent to which the lid to be brought together is marked out Lower lid split to same extent and formation of a small triangular skin flap, removal of roots of cilia from follicles Upper lid split to same extent as lower lid, creating of a raw surface by excision of hair follicles Mattress suture to lift lower lid to upper lid

b Mattress suture tied over small roll of gauze

with the conjunctiva From the median point of the incision, a short incision is carried downward through the skin so that a small triangular flap is formed (Fig 227, *a*) The ciliary follicles along the posterior border of the upper end of the flap are removed by a pair of scissors so that the cilia may afterward fall out

The upper lid is now split by an intermarginal incision, in the same way and extent as the lower lid The bed of the hair follicles is excised, and in this way a raw surface is created to which the skin flap of the lower lid will fit With a mattress suture the lower flap is firmly attached to the raw surface of the upper lid With a few fine sutures, the remaining wound edges are sutured together

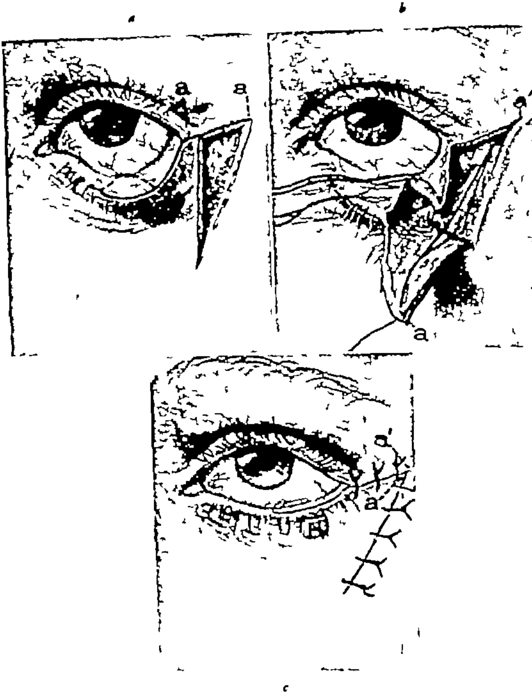


Fig. 226, *a* Repair of complete paralytic ectropion (Kuhnt, Dieffenbach, Szymanowski, Meller) From marginal incision along lateral half of lid, conjunctivotarsal layer is separated from orbicularis skin lamella. Triangular piece of middle section of conjunctivotarsal layer is removed (dotted line) From outer canthus, incision is continued obliquely outward and upward for distance equal to length of base of excised conjunctivotarsal triangle (a-a') From here, incision is carried downward twice as long as a-a Terminal point comes to lie in vertical plane with outer canthus. This terminal point and outer canthus (*a*) are connected with another incision, thus outlining triangular piece of skin which is excised.

b Skin flap median to skin defect is mobilized. Conjunctivotarsal defect is closed by suturing wound edges together

c: Eyelashes are removed between point *a* and outer canthus. Point *a* is sutured to point *a* Mattress suture is placed at center of lid close to lid margin through skin and conjunctivotarsal wound edges.

ENTROPION

Entropion is a condition in which the lid margin is inverted. The entropion may be spastic or cicatricial.

Spastic Entropion

The inversion of the lid margin in spastic entropion is due to an overaction of the orbicularis muscle, and as a rule occurs in old age Excision of a horizontal ellipse of skin and orbicularis muscle immediately below the lid margin may suffice Ziegler's galvanopuncture, however, is said to be more effective The method is similar to that described on p 373. The electrode, however, is inserted on the outside, and penetrates through skin and subcutaneous tissue

Cicatricial Entropion

The inversion of the lid margin in cicatricial entropion is due to destruction and replacement of the conjunctiva by scar tissue, resulting subsequently in deformity and shrinkage of the tarsus It is nearly always due to trachoma In the majority of cases, the condition can be repaired Many operations have been devised, but in the more severe cases, only those procedures which attack the main factor of the deformity—the bent and deformed tarsus—can be regarded as effective Hence, only tarsoplastic procedures may be considered and, of these, one is selected in which a wedge-shaped piece of tarsus is removed This method, originally devised by Streatfield (1858) and perfected later by Snellen (see Van Gils), has been modified in many ways

Technic (for the Upper Lid) (Streatfield-Snellen) (Fig 228) The lid is steadied in a lid clamp, which is long enough to include the entire tarsus The skin is now incised along the outer length of the lid margin and 3 mm (1/8 inch) away from it The upper wound edge is grasped and dissected free from the underlying orbicularis muscle to a point level with the upper border of the tarsus (Fig 228, *a*) The fascia and orbicularis muscle covering the tarsus in the exposed section are now grasped and excised from the tarsal plate Now follows the excision of a wedge-shaped piece of tarsus (with its base outward) from that region where it is most acutely bent (convex), that is, 3 mm (1/8 inch) above the lid margin (Fig 228, *a, b*) The width of the base of the wedge depends upon the severity of the deformity, as a rule, it is from 1 to 2 mm wide The incisions are outlined with a knife while the cartilaginous strip itself is removed with forceps and scissors, care should be taken not to perforate or excise the conjunctiva

After completion of the excision, the lower part of the tarsus can be

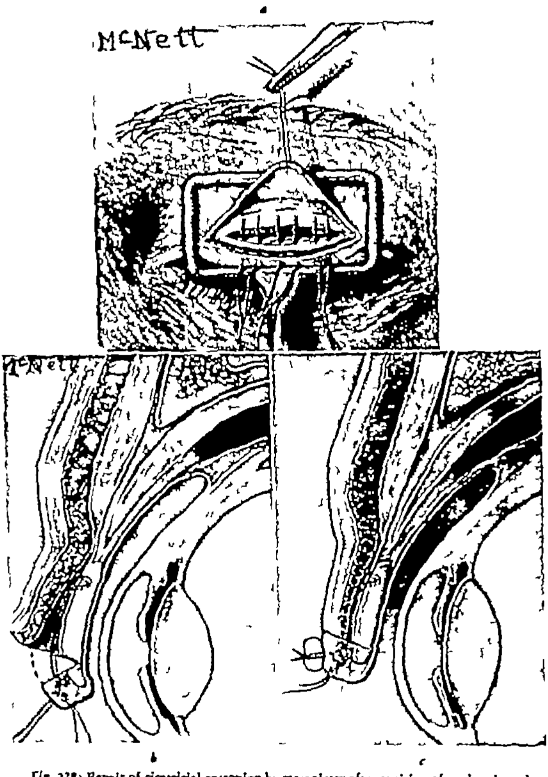


Fig. 228: Repair of cicatricial entropion by tarsoplasty after excision of wedge-shaped piece of tarsus (Streatfield, Snellen) (See text.)

4 Third-nerve regenerating fibers (pseudo-Graefe syndrome)
5 Cervical sympathetic paralysis
6 Atonic ptosis (senility, old enucleation)
7 Neuromuscular
8 Degenerative Blepharochalasis
9 Neoplasm, as, neurofibromatosis
10 Hysterical

Operative Procedures: As to various operative procedures, it is beyond the scope of this book to mention them all None is entirely satisfactory, and no single procedure will meet all problems Most of the operations belong strictly to the ophthalmic field, and should be performed only by those qualified in this field Only the main principles are depicted by classifying the various operative procedures into three groups

1 Shortening or advancement of the musculus levator palpebrae superioris
2 Utilization of the action of the musculus epicranius
3 Utilization of the action of the musculus rectus superior

Indications for Various Procedures The decisive factors are (1) the degree of ptosis, whether incomplete or complete, and (2) whether the musculus rectus superior is functioning or not

If the ptosis is incomplete—that is, the action of the musculus levator palpebrae superioris only weakened—shortening or advancement of this muscle is the operation of choice

If the ptosis is complete and the paralysis of the musculus levator palpebrae superioris associated with paralysis of the musculus rectus superior, utilization of the action of the musculus epicranius is the only choice

If the ptosis is complete and the musculus rectus superior functioning, utilization of the action of the latter muscle is indicated, since it is followed by better functional results than are offered by utilization of the action of the musculus epicranius

Incomplete Ptosis

SHORTENING AND ADVANCEMENT OF MUSCULUS LEVATOR PALPEBRAE SUPERIORIS

The precursor of this group of operations was the folding of the musculus levator palpebrae superioris, as devised by Everbusch (1883) This principle of shortening the muscle was quite unsatisfactory Advancement of the muscle, with or without partial excision of the tarsoconjunctival lamella, was the next logical step

bent outward and held in this position by three mattress sutures, which are led in the following way A silk thread is armed with two small, curved, cutting-edge needles. One needle engages the upper convex border of the tarsus vertically, and the other one does the same thing a little away from the former stitch (Fig 228 *a*) Both threads are now led downward upon the upper tarsal lamella (Fig 228 *b*, *c*) and each thread is stitched through the skin of the lower wound edge emerging above the cilia (Fig 228 *a*, *b*) Two more such sutures are led in a similar way The two ends of each suture are now passed through small plates of rubber (cut from sterile rubber tubing) the lid clamp is removed and after hemostasis the sutures are tied (Fig 228 *c*) Then follows closure of the skin with a few fine silk sutures. The latter are removed after four days the mattress sutures after three weeks.

BLEPHAROPTOSIS

The upper lid is lifted by the contraction of the musculus levator palpebrae superioris In ptosis the action of the muscle may be only weakened or it may be paralyzed completely In the former case, ptosis is incomplete in the latter complete. Ptosis may or may not be associated with paralysis of the musculus rectus superior

The medical profession is indebted to E. B Spaeth for his efforts in clarifying the underlying physiological principles as related to proper therapy Ptosis may be congenital or acquired unilateral or bilateral

Classification of Congenital Ptosis Spaeth classifies the congenital cases into the following groups

1 Unilateral ptosis without involvement of the superior rectus muscle.
2. Unilateral ptosis with involvement of the homolateral superior rectus muscle
3 Bilateral ptosis without involvement of the superior rectus muscle.
4 Bilateral ptosis with involvement of the superior rectus muscle.
5 Unilateral ptosis with weakness of both superior rectus muscles.
6. Ptosis with more or less complete third nerve and even sixth nerve paralyses.
7 Ptosis with the classical jaw winking reflex.
8 Ptosis with Duane's retraction syndrome.
9 Ptosis with neurofibromatosis.

Classification of Acquired Ptosis. Spaeth classifies the acquired cases into the following groups

1 Traumatic (peripheral, cicatricial)
2 Traumatic (central and cerebrospinal) essentially sympathetic nerve paralysis.
3 Third nerve paralysis.

each end of the mattress suture is passed through the anterior surface of the tarsus and conjunctiva about 4 mm (5/32 inch) above the lid margin, about 3 mm (1/8 inch) below, the suture reenters the conjunctiva and tarsus, passes through the entire thickness of the lid, and emerges through the skin of the lid near the lid margin The sutures are passed through a

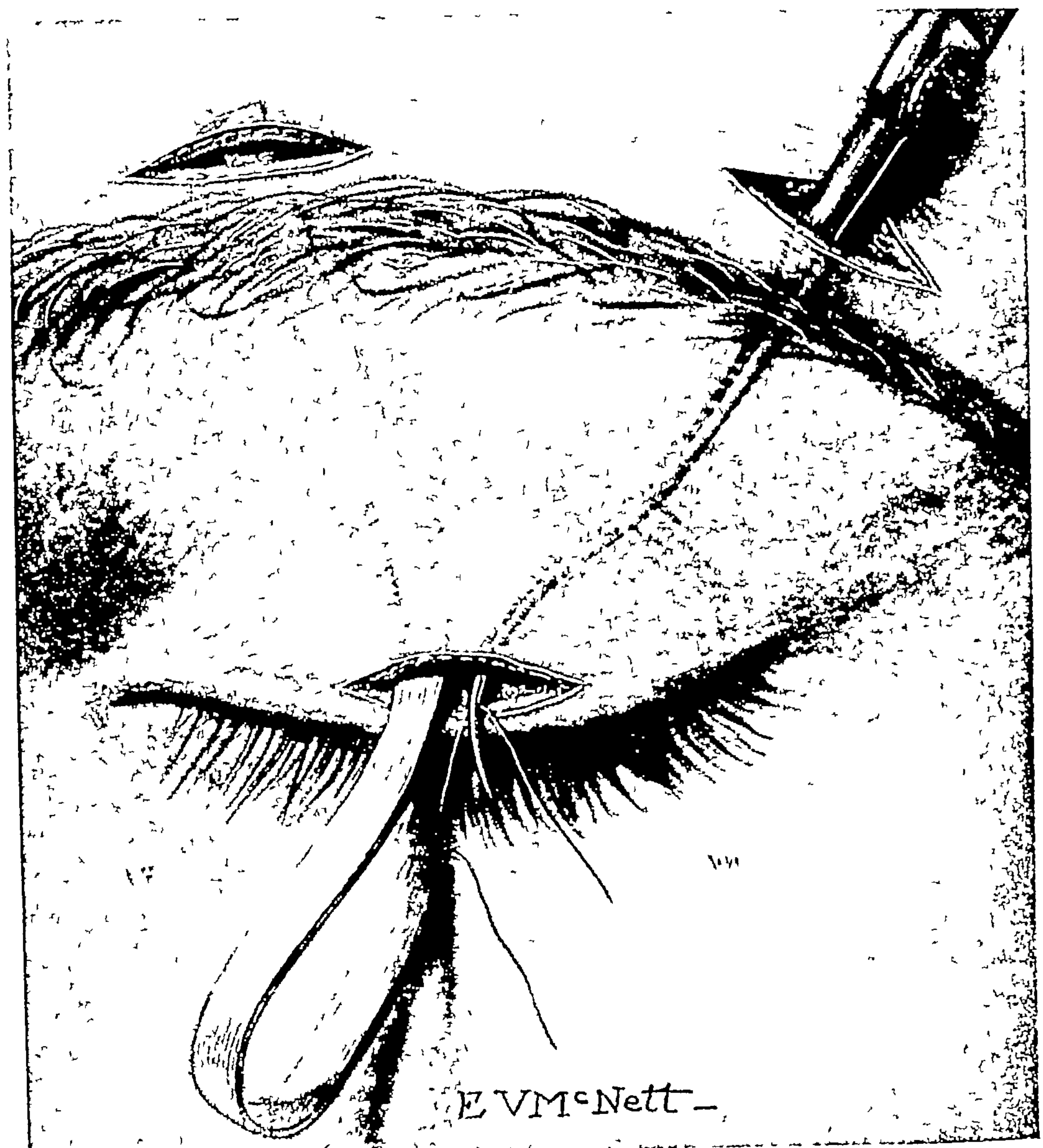
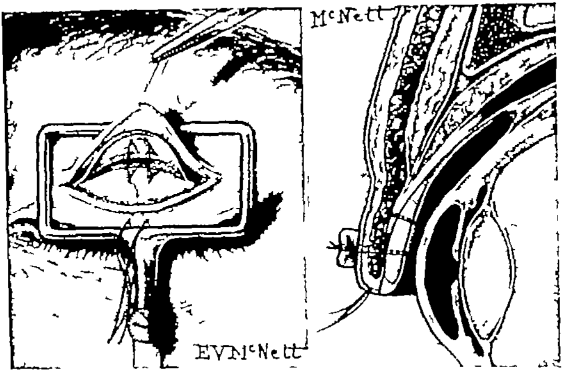


Fig 230, *a* Utilization of musculus epicranius in ptosis operation (Wiener) From two small incisions in skin just above brow, musculus epicranius is exposed Another small incision is made 4 mm (3/16 inch) from and posterior to lid border, exposing tarsus Narrow strip of fascia is now inserted as follows Mattress suture is placed through each end, Reverdin needle (or small probe with an eye) is passed from median opening over brow, subcutaneously under skin of lid and emerging at opening over tarsus Thread is attached to one of fascial strips, fastened to needle which is then withdrawn, pulling fascial strip through brow opening This free end is then firmly sewed to tendon of musculus epicranius Same procedure is performed over lateral opening

Technic (Elschnig) (Fig 229) After application of a lid clamp an incision is made 1.2 cm (1/2 inch) above the lid margin and parallel to it, through skin and orbicularis muscle The upper border of the tarsus and the septum orbitale are dissected free. The septum orbitale is severed 3 mm (1/8 inch) above the tarsus along the entire length of the latter exposing the levator lamella beneath The levator lamella is secured



a b

Fig. 229 a Ptosis operation. Shortening and advancement of musculus levator palpebrae superioris (Elschnig) From horizontal incision, 12 mm. (1/2 inch) above lid margin, skin orbicularis and fascia are severed 3 mm. (1/8 inch) above tarsus and retracted (traction suture) Levator muscle is secured with three mattress sutures (only one depicted in drawing) 5 to 10 mm. (3/16 to 3/8 inch) above tarsus. Levator muscle is severed horizontally below sutures. After subfascial dissection of tarsus from lower wound edge, levator muscle is advanced as depicted in b b Each end of mattress suture is passed through anterior surface of tarsus and conjunctiva about 4 mm. (3/16 inch) above lid margin. About 3 mm. (1/8 inch) below suture reenters conjunctiva and tarsus, passes through entire thickness of lid, and is tied over small piece of rubber

with three silk mattress sutures which are placed through the muscle 5 to 10 mm (3/16 to 3/8 inch) above the tarsus Then follows subfascial dissection of the tarsus from the lower wound edge until the lid margin is reached The musculus levator palpebrae superioris is now severed below the sutures in its entire length

The next step is the advancement of the levator by retracting the lower wound lamella the tarsus is exposed the three mattress sutures securing the upper levator lamella are placed as demonstrated in Fig 229

to its border, through skin and musculus orbicularis oculi to the tarsus, the lid clamp having previously been applied to avoid bleeding (as in Fig 229) The skin is freed from the underlying tissue, and that part of the musculus orbicularis oculi attached to the tarsal plate is removed with straight blunt-pointed scissors The clamp is then removed and pressure exerted with a gauze sponge to control the bleeding

A narrow strip of fascia is now removed from the thigh (see p 45) A mattress suture is placed through each end A Reverdin needle or a small probe with an eye is passed from one of the openings over the brow, subcutaneously under the skin of the lid, emerging at the opening over the tarsus The threads attached to one end of the fascial strip are fastened to the needle, which is then withdrawn, pulling the end of the fascial strip out through the brow opening This is then firmly sewed to the tendon of the musculus epicranius, the threads cut short, and the end of the strip tucked under the upper skin flap

The instrument is then passed through the other brow incision under the lid skin, emerging at the opening over the tarsus, and the suture through the opposite end of the strip is attached to the instrument, which is then withdrawn to the brow opening Before it is pulled tight, a round toothpick or a section of a wooden applicator is passed through the loop of fascia When traction is then made on the fascial strip from the brow opening, the piece of wood passed under the loop prevents it from rising too far and disappearing under the skin fold

Just enough traction on the strip is made to raise the lid to the degree judged by the surgeon to be adequate The free end of fascia is then attached to the tendon of the musculus epicranius, as was the first In this manner, equal traction is exerted in raising the lid from each side of the brow Two sutures are placed, fastening the loop of fascia securely to the tarsal plate, one on each side Then follows closure of the skin incisions

The author (May) has slightly altered this technic (Fig 230, *b*) After the fascial loop is placed, the toothpick inserted, and the loop placed under proper tension, one free end of the fascia is attached to the musculus epicranius, the lower end to the tarsus The toothpick is then removed, the other part of the loop pulled to assure equal tension, and its free end sutured to the musculus epicranius A second suture may now be inserted to the other part of the angle of the loop In this way, puckering of the angle of the loop is avoided

Hendrix describes a simpler method, which has been devised by Sawar, a British ophthalmologist Instead of a strip of fascia, a transverse strip of the upper fibers of the orbicularis oculi is used as a sling and thus may act as a dynamic support

small piece of rubber (cut from rubber tubing) and tied. Then follows closure of the fascia and skin For after treatment, see p 585

The skin sutures are removed on the fifth day the advancement sutures on the tenth day

Complete Ptosis with Paralysis of Musculus Rectus Superior Utilization of Action of Musculus Epicranius

The results which Kirschner obtained in using fascia grafts to transfer the action of the musculus epicranius to the paralyzed musculus levator

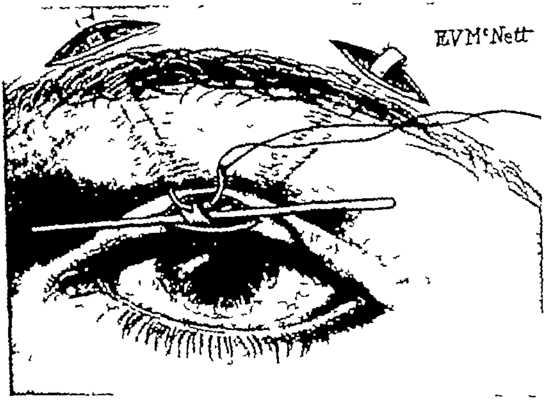


Fig. 230 *b:* Before pulling lateral strip tight, round toothpick is passed through angle of loop traction is then made on fascial strip. Toothpick prevents loop from rising too far One suture is now placed through median part of loop, fastening fascia graft to tarsus. After this suture is placed, toothpick is removed, equal pull is exerted on lateral part of fascial loop, and free end sutured to musculus epicranius. (Wiener and Alvis Surgery of the Eye W B. Saunders Co.)

palpebrae superioris were so good that Pagenstecher's and similar sutures were abandoned. Lexer modified Kirschner's procedure and improved the cosmetic result. Wiener simplified the latter's method

Technic (Wiener) (Fig 230) An incision from 1 to 1.5 cm. (3/8 to 5/8 inch) long is made in the skin just above and parallel to the brow at about the middle of its outer half and a similar incision at about the middle of its inner half to expose the tendon of the musculus epicranius An incision is now made in the lid 4 mm. (5/32 inch) from and parallel

many modifications of the original operation have been devised This operation is strictly an ophthalmic operation, to be performed by the ophthalmic surgeon.

Technic (Motais) (Fig 231) · The upper lid is everted. A fine retractor engages the sclera 3 or 4 mm ($\frac{1}{8}$ or $\frac{5}{32}$ inch) above the cornea and rotates the eyeball downward A second retractor engages the free border of the tarsus, pulling the latter upward Thus, the upper fornix is exposed

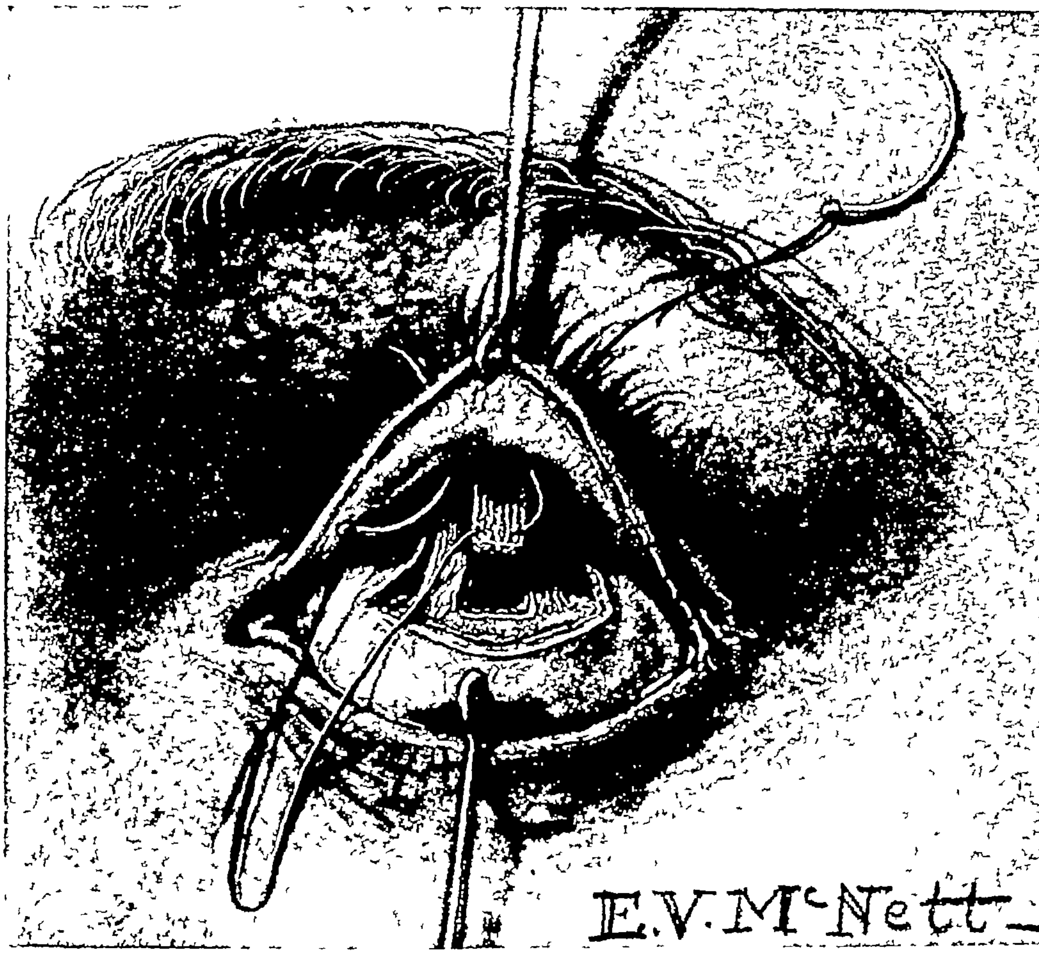


Fig 231 Utilization of action of musculus rectus superior in ptosis operation (Motais) (See text)

About 5 to 7 mm ($\frac{3}{16}$ to $\frac{9}{32}$ inch) above the margin of the cornea, a T-shaped incision is made through the conjunctiva The wound edges are undermined until the tendon of the musculus rectus superior is exposed The middle section of the tendon is now grasped with a forceps, and a piece of it, 3 mm ($\frac{1}{8}$ inch) wide, is severed from the sclera either with a fine scalpel or with fine, curved scissors This section of the tendon is lengthened backward for about 1 cm ($\frac{3}{8}$ inch) The peripheral end

Technic (Sawar) Two parallel incisions are made One is similar to the lower incision of Fig 230 *a* only longer and the other one is immediately inferior to the supraorbital margin of the orbit. From this latter incision the upper fibers of the orbicularis oculi muscle are exposed and a strip 3 mm ($\frac{1}{8}$ inch) in width and 3 2 to 4 4 cm ($1\frac{1}{4}$ to $1\frac{3}{4}$ inches) in length is raised. One side median or lateral is detached. A wide tunnel is made between orbicularis and levator muscles The latter is severed from the upper rim of the tarsus and the conjunctiva is detached from the posterior surface of the tarsal plate A small incision is made through the tarsus near its superior border A mosquito hemostat is now inserted through the slit in the tarsal plate and pushed upward through the previously made tunnel to grasp and pass the orbicularis strip downward through the tarsal plate and then upward upon the tarsal plate through the same tunnel toward the original insertion of the strip The free end of the muscle strip is sutured back into the spot from which it had been attached after the lid has been pulled up sufficiently (see foregoing technic)

Sawar believes that this kind of suspension is rather dynamic than static. Hendrix claims that this method is easily executed but depends much upon proper muscle training for good results hence it appears to be contraindicated in children

After Treatment In applying a dressing two thoughts must be held uppermost (1) the cornea must be protected and (2) there must be no traction or pull on the upper lid which will compromise the stitches placed to hold it in position This is accomplished by covering the eyeball with the lower lid

After cheek and lower lid have been raised enough to cover the cornea a broad piece of adhesive is attached to the cheek a light gauze dressing placed over the upper lid and brow and the other end of the adhesive strip fastened to the forehead This protective dressing is required for only a few days but it must be applied at night for protection as long as the lids will not close enough of themselves to cover the cornea during sleep The patient must be observed during sleep to determine this

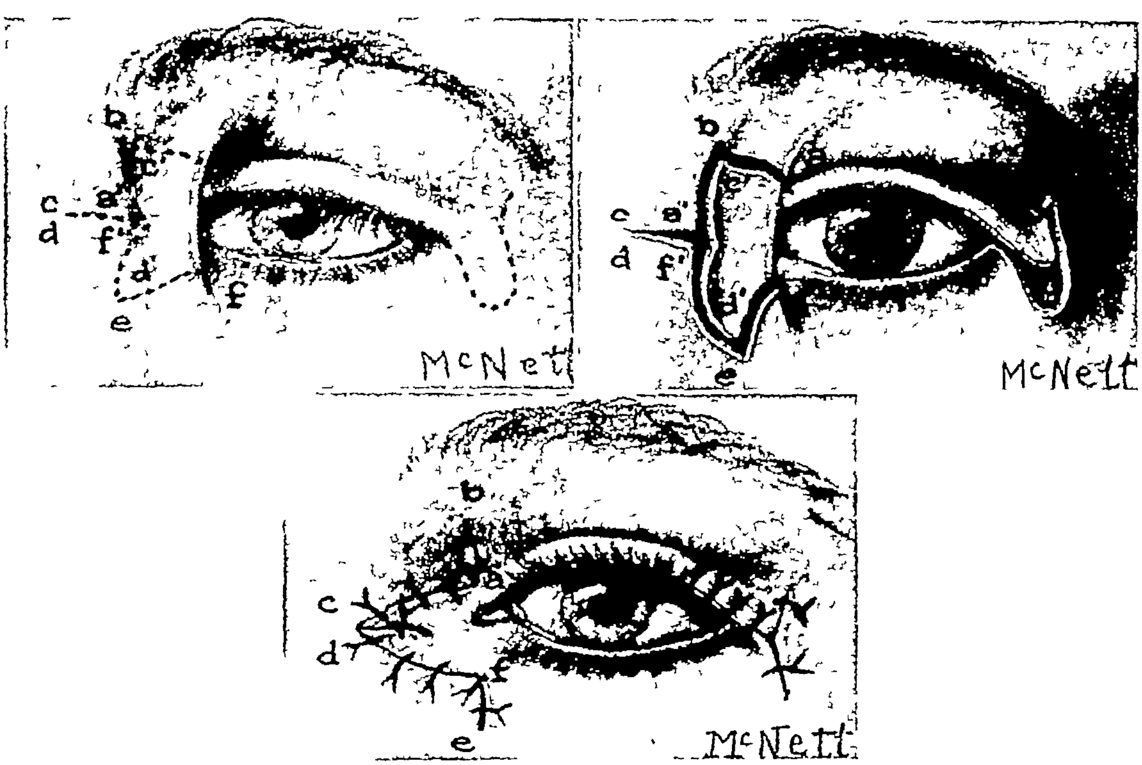
Complete Ptosis without Paralysis of Musculus Rectus Superior

UTILIZATION OF ACTION OF MUSCULUS RECTUS SUPERIOR

An entirely new principle in the treatment of complete blepharoptosis was introduced by Motais (1903) by transferring the action of the musculus rectus superior to the paralyzed upper lid. Since that time

To widen the lateral fissure, a canthotomy, about 3 to 4 mm. (1/8 to 5/32 inch) long, is made with scissors, separating skin, muscle, palpebral fascia, and conjunctiva, from here the incision curves downward and temporally for about 5 mm. (3/16 inch), then upward and medially, terminating about 7 mm (9/32 inch) lateral to and 5 mm (3/16 inch) above the canthus, separating skin, muscle, fascia, and external palpebral ligament. Thus, a rounded, triangular flap is outlined, which is mobilized,

a *b*



c

Fig 232, *a* Epicanthus operation (Blair, Brown, Hamm) Formation of two upper and two lower triangular flaps Flap at outer canthus to widen lateral fissure

b Flaps are being mobilized

c Triangular flaps are exchanged Lateral fissure is widened after elevation of upper lid and flap

also mobilized by undermining is the lateral (temporal) side of the wound edge, while the median wound edge (the continuation of the lower lid) is left intact The conjunctiva is now undermined with scissors and sutured to the lower lid for about 3 to 4 mm (1/8 to 5/32 inch) At the upper lid, however, the conjunctiva is further sutured laterally to facilitate raising of the lid The next step is approximation of the conjunctiva and skin of upper and lower lid to form the new canthus Then follows the closure of the remainder of the wound

of this tendon flap 3 mm wide and 1 cm. long is engaged in a double-armed fine-silk suture, the loop being made to lie posteriorly

With a small scalpel an incision is made through the levator muscle in the upper extremity of the T incision at the upper border of the tarsal plate and parallel to its upper border The tarsal plate is pulled downward with a forceps and the insertion of the levator as well as the fascia, is severed with curved scissors from the tarsus for about 4 mm (5⁄32 inch) From here the anterior surface of the tarsus is dissected free to a point 3 to 4 mm (1⁄8 to 5⁄32 inch) from the line of cilia

The two needles of the double armed suture are now passed through the levator incision between the anterior surface of the tarsus and the musculus orbicularis oculi to emerge through the skin 3 mm (1⁄8 inch) from the lid margin The conjunctival wound is now closed and the sutures are tied over a roll of gauze tightly enough to overcorrect the ptosis slightly

For after treatment see p 385

EPICANTHUS

Epicanthus, a characteristic feature of the Mongolian race is a skin duplication due to vertical shortness of the tissue connecting the upper and lower lid at the inner canthus and bridging the latter It may be congenital or acquired Correction of the congenital form can usually be obtained by flap-switching which adds vertical length at the expense of the transverse redundancy (Blair Brown and Hamm) In the traumatic type a Z-operation (p 147) may be sufficient, or excision of the scar and skin-grafting or the use of local flaps may be required.

Technic (Blair Brown Hamm) (Fig 232 Case 64 p 932) The principle is the formation of two upper and two lower triangular flaps which are interchanged as in a Z-operation To form the two upper triangular flaps a horizontal incision about 7 mm (9⁄32 inch) long is made through the skin nasally starting from a point 5 mm (3⁄16 inch) away from the canthus. From the starting point a slightly curved incision is led upward and parallel to the fold of the epicanthus for about 7 mm (9⁄32 inch) From the termination of this incision another incision is led downward ending at the margin of the upper lid 4 mm (5⁄32 inch) from the canthus. Two similar incisions are made in the lower half. Thus four triangular flaps are outlined (the lateral two have one side in common) and are now thoroughly mobilized beyond their bases They are then exchanged first the two upper second the two lower ones They are held in position by sutures.

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Technic (Spaeth) The anterior fold of the epicanthus is utilized as two triangular flaps with a common tip in the center of the fold and their base in the upper and the lower part of the fold In other words an \ shaped incision is made on the anterior surface of the fold. The upper of the two triangles is mobilized and moved into the upper lid the lower of the two into the lower lid To facilitate a smooth fitting of the flaps additional incisions are made into the upper and lower lid across the edge of the epicanthal fold for a distance equal to the length of the triangular flaps and the skin of upper and lower lid is undermined

Fig. 233 a. Correction of redundant skin of lower lid. Removal of elliptical piece of skin. Upper incision runs close to lid margin. Lower incision diverges laterally where triangular piece of skin is removed to avoid puckering. b Wound edges sutured together

REDUNDANT SKIN OF EYELIDS

Redundant skin may merely cause excessive lid wrinkles and be disturbing cosmetically but the condition may be of such degree that pouches are formed These pouches are mainly due to herniation of intraorbital fat Hence there are two conditions and they are not synonymous In the case of simple redundancy only the skin of the lids is involved With pouches however the intraorbital fat has herniated causing the skin redundancy This distinction has much bearing on therapy In simple redundancy excision of skin alone is enough but in herniation of fat, the fat pouches must be removed primarily The subject has been extensively covered by Castanares

Technic. *Upper Lid* Under local anesthesia of which as little as possible should be used—or even better under general anesthesia—an elliptical piece of skin of the proper size is removed. The incision should be placed so that the suture will come to lie in a natural fold.

The wound edges are sutured together with fine silk.

HOLES IN CONCHA

Technic (Small Hole) (Case 65, p 933) A double-pedicle flap is formed in the retroauricular region posterior to the hole in direct continuation of the defect. The site of the lateral pedicle is the skin of the posterior rim of the hole, that of the median pedicle, the mastoid region The flap should be made one third wider than the defect This bridge flap, remaining attached at the lateral and median pedicles, is undermined and returned to its original site In the same sitting, a small rim of the skin surrounding the edge of the defect is mobilized from the

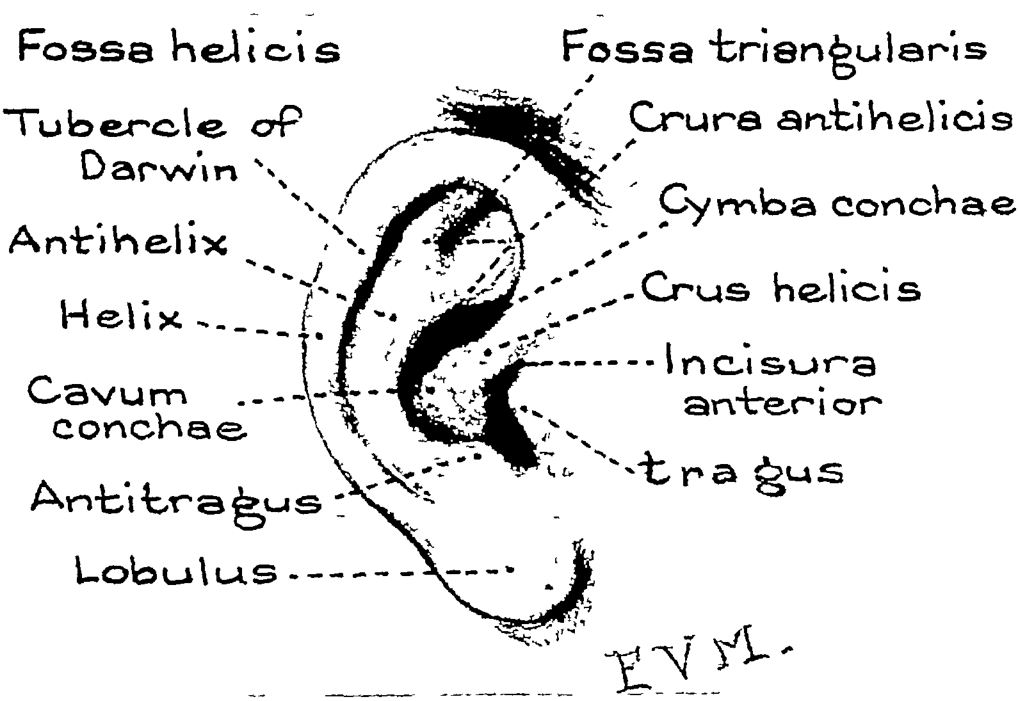

Fig 234 Anatomy of auricle

underlying cartilage, and returned to its original site The reason for mobilization of this rim of skin is twofold. (1) to prepare hinge flaps of skin which later are turned inward and forward, forming the anterior covering of the hole, (2) by exposing the cartilages, a firmer base is created on which the peripheral end of the bridge flap can rest more firmly than if sutured to the rim of the hole.

The lateral pedicle of the flap near the hole is severed after two weeks and sutured

After two more weeks, the entire flap is mobilized, the rim of skin surrounding the defect is again mobilized and turned inward and forward; the flap is now sutured into the defect Since the flap cannot be moved forward to reach the outer edge of the defect, the ear is tilted

XI

THE EXTERNAL AUDITORY STRUCTURES

LESIONS of the auricle may be congenital or acquired. In congenital lesions or lesions acquired in childhood reconstruction should be undertaken after the patient has matured For psychological reasons, however it may become necessary to operate earlier

Anatomy The auricle, or pinna is a skin duplication with a cartilaginous plate as a framework (Fig 234) The skin is firmly adherent to the anterior surface of the cartilage but movable on the posterior side The auricle is funnel shaped and leads into the external auditory canal The posterior and upper rim of the auricle the helix bends acutely forward. The anterior portion of the helix assumes a backward curve called the crus helicis which passes over into the concha In front of the helix almost parallel to it is another rim the anthelix It commences in the upper part of the auricle with two converging limbs the crura anthelicis and in the lower part passes over into the antitragus Between the latter and the tragus is the incisura intertragica The tragus is a small cartilaginous plate which like a valve overhangs the external auditory canal The deep fossa between tragus and anthelix is the concha

Defects

Defects of the external ear may be partial or complete. Smaller defects can as a rule be closed by the use of local flaps. Larger defects or absence of the entire auricle can also be corrected by local flaps in the majority of cases but require more complicated procedures making the reconstruction one of the most difficult tasks in reparative surgery

Technic (Large Holes) (Fig 235) Large holes are closed with a lined flap from the hairless mastoid region A suitable flap, one third wider than the defect, is outlined, as demonstrated in Fig 235, *a* The posterior edge at the base is curved backward to facilitate later rotation The peripheral half of the flap is mobilized and returned and sutured to its original site

After two weeks, the entire flap is mobilized, and that part of the flap which is to cover the defect is lined with a skin graft The flap is returned to its original site After two more weeks, the flap is again mobilized, a rim of skin surrounding the defect is removed from the underlying cartilage, the flap is rotated into the defect and sutured in place The peripheral part of the flap bed is covered with a full-thickness graft

After three weeks, the pedicle of the flap is severed and returned to its original base, the flap itself is adjusted in place

PARTIAL DEFECTS OF CONCHA AND HELIX

Defects of the rim of the helix and part of the anthelix are reconstructed with a flap from the mastoid region The flap is raised in one stage and sutured into the defect (see Case 66, p 934) The pedicle of this flap is gradually severed after about three weeks and folded posteriorly Larger defects of concha and helix are repaired with flaps from the mastoid region Nélaton and Ombrédanne modified Dieffenbach's method A flap, pedicled in the mastoid region, is raised and sutured to the anterior cutaneous borders of the defect After several months, the pedicle is severed and the flap raised and sutured to the remaining edges of the defect

Technic (Defect of Entire Upper Half of Ear): (Cases 67, 69, pp 935, 937) The preserved parts of the ear are laid upon the mastoid region, and between them a flap, which is to replace the defect, is outlined To counteract shrinkage, the flap is made somewhat larger than required This flap is raised as a bridge or double-pedicle flap with an anterior pedicle at the margin of the defect—that is, at the base of the concha—and a posterior pedicle, and is returned to its original site (In case of scar formation between anterior pedicle and defect, the scar should be excised and the skin edges accurately approximated to produce a minimum of scar and a maximal blood supply This procedure should be performed four weeks before the formation of the flap If the posterior part of the flap comes to lie in the hairy scalp, depilation is required in the same stage, as described on p 198)

After two weeks, the posterior pedicle is severed and sutured After two more weeks, the entire flap is raised, a piece of autogenous rib car-

backward. After the flap is sutured in place, the ear is kept approximated to the skull with adhesive strips.

If after three weeks the ear is still tilted backward, the central pedicle of the flap in the mastoid region is severed, the median half of the flap is mobilized, the ear is moved to normal position, the flap is sutured to its new base, and the secondary defect resulting from moving the flap forward is skin-grafted.

a b

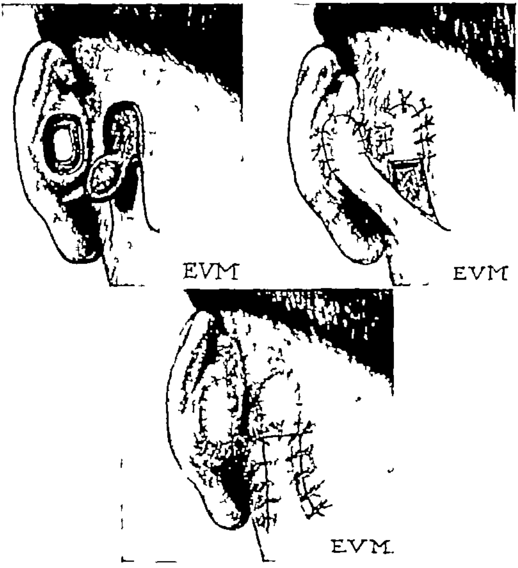

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Fig. 235, a. Closure of hole in concha. Single-pedicle flap is raised in stages from hairless mastoid region. Its peripheral end is lined with skin graft and flap returned to its original site.

b: Flap is raised again, rotated, and sutured into defect. Peripheral end of flap bed is skin-grafted.

c: After severance of pedicle and adjustment of pedicle and flap.

or a preoperatively made model as a guide (It helps to leave the perichondrium on the anterior side of the concha intact and to thin the concha part of the cartilage on the posterior side The perichondrium tends to contract, thus facilitating the cup shaping) The graft is now buried in anatomical position in the previously made pocket. The wound

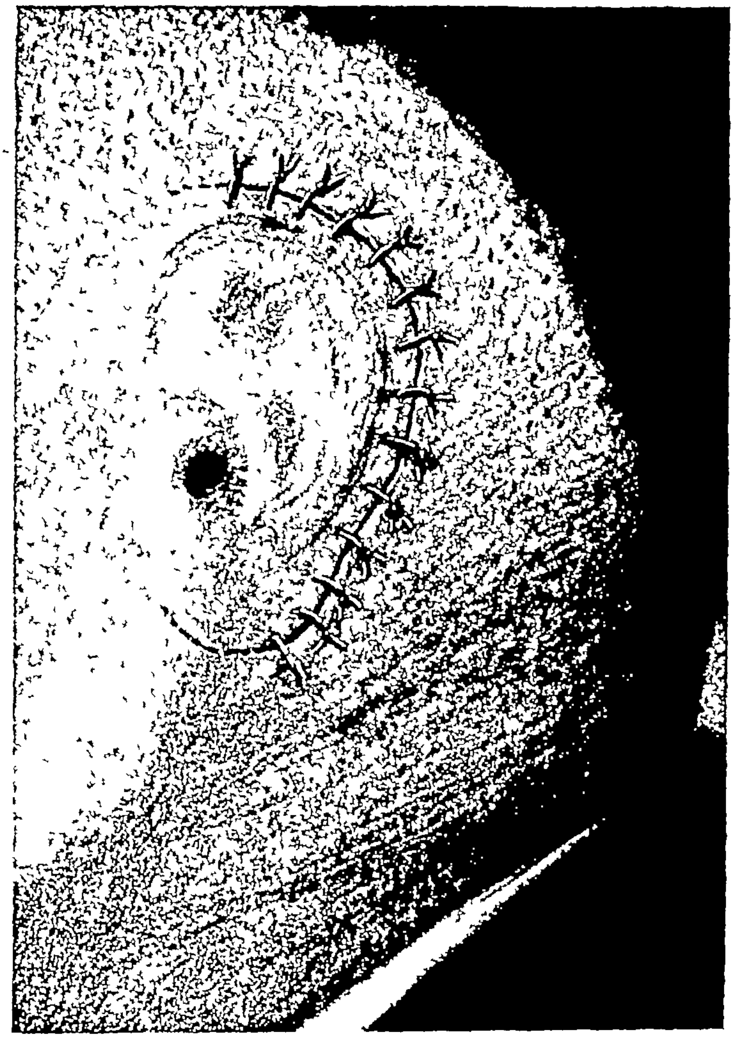


Fig 236, *a* Reconstruction of total ear First stage Flap from mastoid region, larger than size of other ear, has been elevated from curved incision along proposed helix Cartilage graft, carved to form concha, anthelix, and helix, has been inserted into pocket beneath flap Wound is closed Dotted lines indicate extension of incisions in final stage of reconstruction

is then closed A mold of dental compound is now made, with which the skin overlying the cartilage graft is pressed into the convolutions of the graft A moderate pressure dressing is applied

Stage 2 If the posterior part of the flap comes to lie in the hairy region of the scalp, it must be depilated (see p 198) This is done four weeks after the first operation.

tilage is carved to replace the missing part of the helix, anthelix and concha and is inserted in the flap bed the flap is returned to its former site and sutured. A pressure dressing is applied. (Making a helix by turning the posterior part of the flap upon itself has not been successful in the author's hands.)

After eight weeks the entire flap with the cartilage graft is raised. To avoid tearing the skin from the underlying cartilage graft while raising the compound flap it is well to place traction sutures through skin edges and cartilage graft after the skin incision is made. Furthermore, in raising the flap care must be taken not to expose the posterior surface of the graft but to leave a sufficient amount of soft tissue upon it. The edges of the remaining defects of the ear are denuded The edges of the flap are sutured to the edges of the defect.

Dental compound is softened in warm water and molded to the posterior surface of the ear and the raw surface of the flap bed care being taken that the ear assumes the same angle of protrusion as the other ear A thick split graft is removed and with its raw surface outward wrapped around the mold and held in this position with cross-sutures (as in Fig 236 c) Mold and graft are placed behind the ear and anchored in this position with mattress sutures through the rim of flap and skin graft and through the posterior edge of the flap bed A mastoid pressure dressing is applied to the ear and should remain in place for ten days When the dressing is changed mold sutures, and overhanging parts of the graft are removed.

TOTAL DEFECT OF EXTERNAL EAR

Reconstruction of a total ear is a difficult but gratifying task in reparative surgery Various methods are available none is ideal (Pierce Gillies Greeley Padgett Kirkham Peer Benson Aufricht, and others)

Technic (Fig 236 Case 70 p 938) The principles are similar to those described in the foregoing paragraphs utilizing a flap from the mastoid region (to be depilated if necessary) burying an autogenous cartilage graft elevating the flap and closing the posterior raw surfaces with a skin graft The flap can be raised in one stage since its pedicle (anterior base of future ear) is sufficiently wide. It can be narrowed if necessary in the final stage (Fig 236 a—dotted line)

Stage 1 The flap somewhat larger than the other ear is outlined in the mastoid region A curved incision along the proposed helix is made The skin is undermined widely in front of the incision A piece of cartilage removed from the fused parts of the seventh eighth and ninth ribs is carved to form a concha anthelix and helix using the other ear

mated with interrupted skin sutures The defect in front of the flap is closed by skin-sliding or skin-grafting (Fig 236, *c*) If no auditory canal exists, the skin flap is raised from the region of the concha, and is folded on itself, the resulting raw area is skin-grafted This procedure deepens

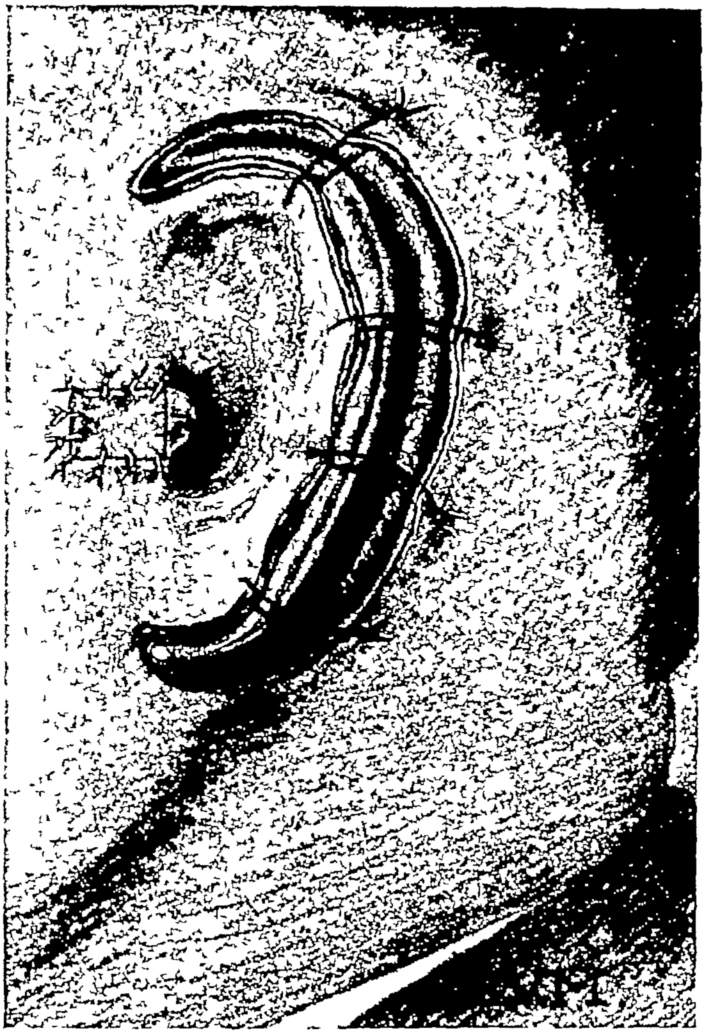


Fig 236, *c* Mold of dental compound is made to fit raw area behind new ear, and to hold elevated flap in same degree of protrusion as other ear Thick split graft, with its raw surface outward, is wrapped around those parts of mold which come to lie upon raw surface behind ear Graft is held in place with cross-sutures Mold and graft are then placed behind ear and held in place with sutures through rim of flap and skin graft, and through posterior edge of skin graft and flap bed If tragus is missing, it can be reconstructed by raising rectangular flap in front of proposed tragus and folding upon itself Raw area of flap bed is closed by skin-sliding or skin-grafting

the concha at the same time It, however, should be postponed, since it might interfere with the circulation of the main flap

Dressing, sutures, mold, and overhanging pieces of the skin graft are removed after ten days

Stage 3 Eight weeks after the first operation flap and cartilage graft are raised. To avoid tearing the skin from the underlying cartilage graft while raising the compound flaps traction sutures should be placed through skin edges and cartilage graft after the skin incision is made Furthermore in raising the flap care must be taken not to expose the

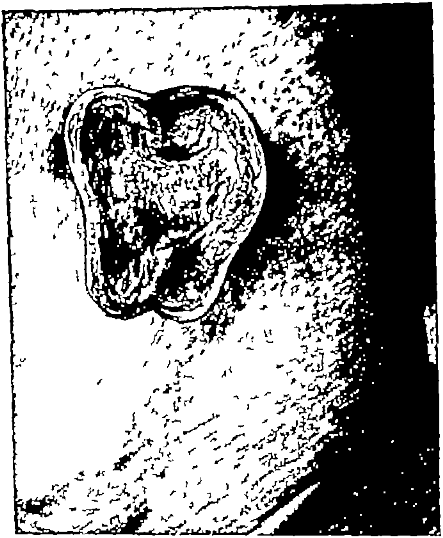


Fig. 236, *b* Final stage: Eight weeks later flap and cartilage graft are raised, care being taken not to expose graft, but to leave sufficient amount of soft tissue upon graft.

graft but to leave a sufficient amount of soft tissue upon it. The flap is elevated to the same degree of protrusion as the other ear and is held in this position with a skin graft wrapped around a mold of dental compound (Fig 236 *c*)

If the tragus is missing it can be reconstructed by Kirkham's method A rectangular skin flap with its base in the position of the tragus is raised from the skin of the face and folded on itself its edges are approxi

about 2.5 cm (1 inch) in diameter with its base in the mastoid region. It is made long enough to be carried over the ear. Its inferior pedicle is gradually severed after four weeks and transferred and sutured just above the tragus. Three weeks later, the base of the tube flap over the mastoid process is gradually severed, the seam of the flap opened, and the flap draped around the auricle in such a way as to complete formation of the helix. If the tube flap must be made very thin, it may be necessary

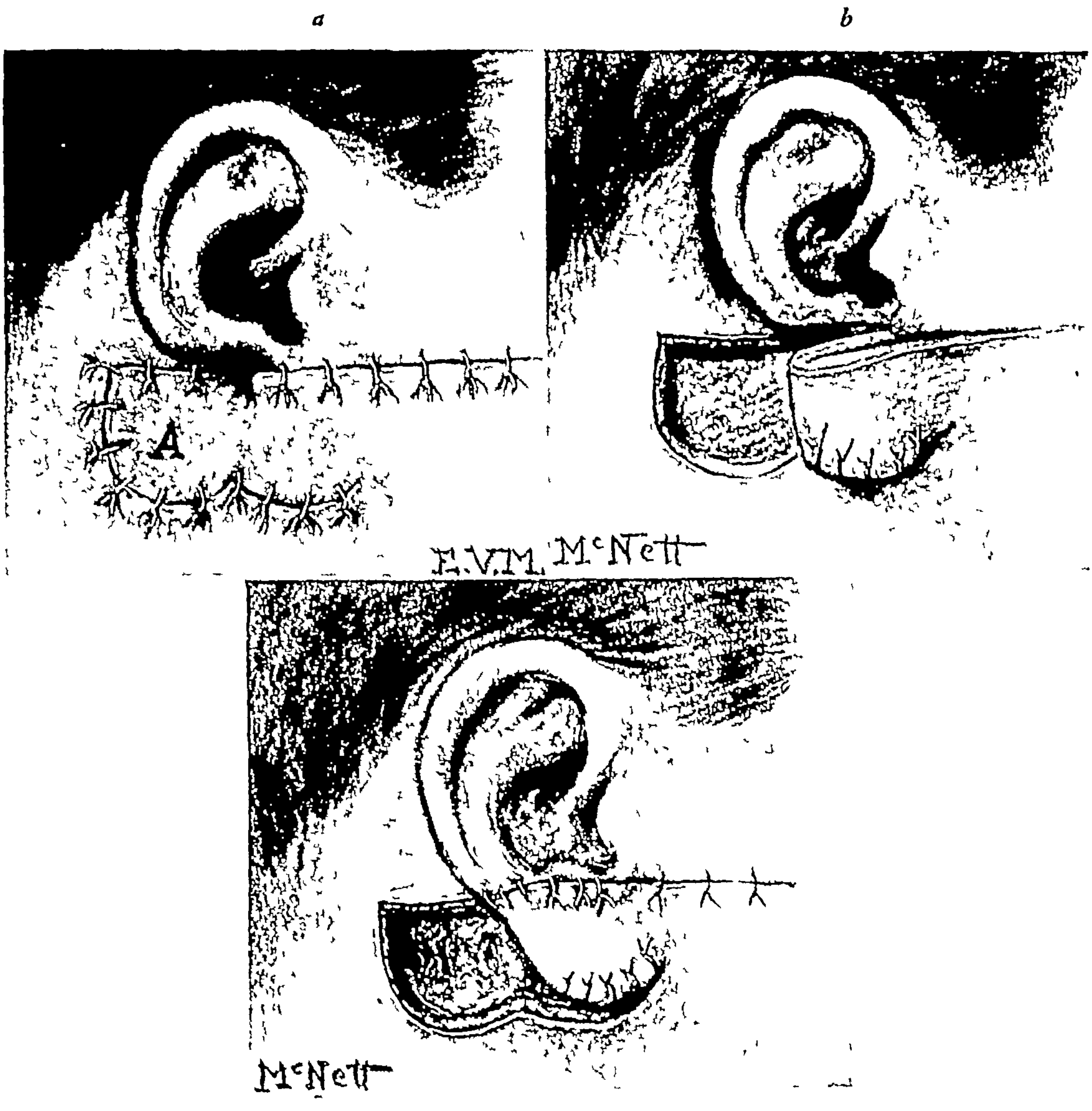


Fig 237, *a*. Reconstruction of lobule (Cavallo). Flap is used from mastoid region with anterior pedicle. In first stage, posterior half, *A*, is raised and returned. In second stage, entire flap is raised and returned, as depicted in drawing.

b In third stage, flap is raised and folded upon itself.

c: Upper edges are sutured to defect's edges. Raw surface of flap bed is closed by undermining and skin-sliding or skin-grafting.

If the flap shows a tendency to fall backward owing to shrinkage of the skin graft the skin-graft procedure must be repeated. Other corrections are also usually necessary to give the ear its final shape These operations may be performed in one or two stages depending upon the circulation in the anterior skin The latter is elevated from an incision along the helix the fibrous tissue between skin and cartilage is removed By excision of cartilage between helix and concha a normal depth is created in this region simultaneously giving the helix prominence much cartilage is removed from the concha leaving prominent ridges to accentuate the crura. The use of a dental burr is of great help in performing this task. The skin flap is then returned and held in place with mattress sutures. These sutures are inserted through the posterior surface of the auricle to draw the free margin of the skin flap into the cartilage groove and are tied on the posterior surface (Peer) Additional simple sutures are unnecessary

In the absence of the external auditory canal the author agrees with Greeley that no attempt should be made to reconstruct it in case of coincidental deafness. From the practical standpoint these patients seem to hear well from the use of their normal ear thus making additional surgery unnecessary If however it needs reconstruction the simplest way is to open the external canal—to counteract shrinkage the opening should be made one third larger than required—and line the raw surface of the canal with a skin graft wrapped around a mold of dental compound (see p 37) The mold is removed after ten days for cleansing and then reinserted until the stage of shrinkage has passed J E Davis however advises opening the antrum before skin-grafting since it improves the hearing He operates in two-stages and his technic requires the skill of a competent otolaryngologist rather than of a plastic surgeon He also emphasizes the need to correct the atresia before reconstructing the external ear

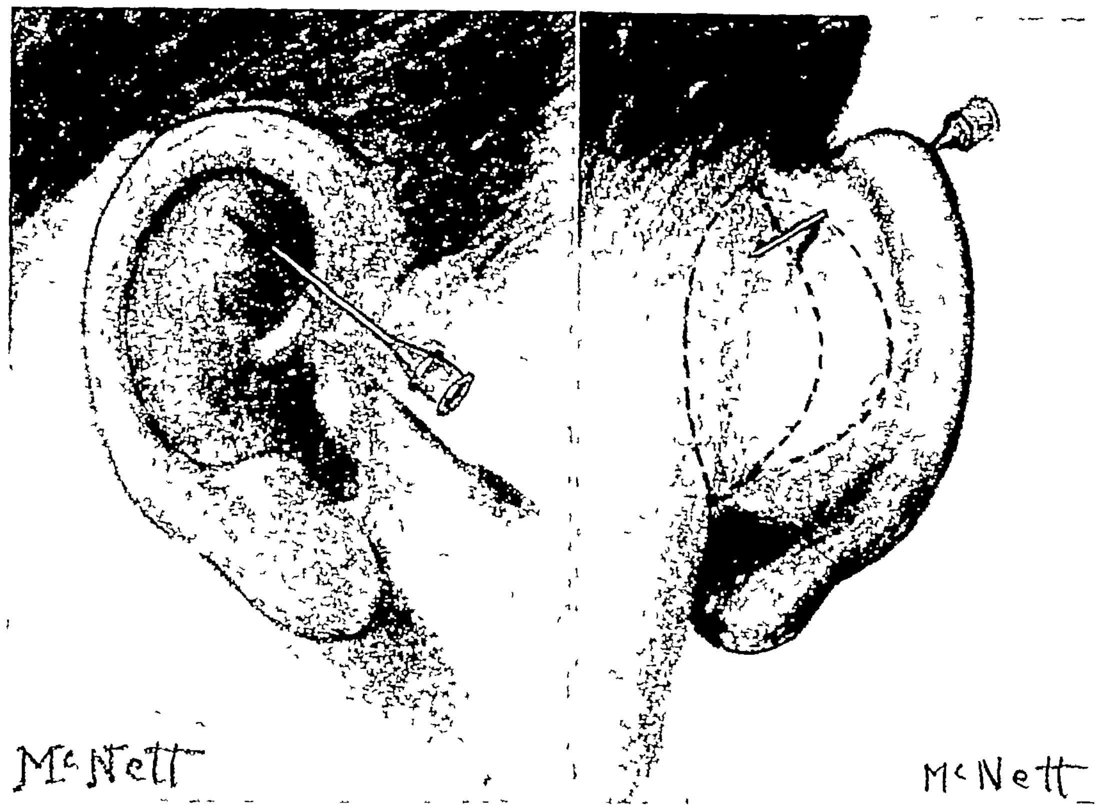
Variation: If the skin of the mastoid region is destroyed it must be replaced by an arm neck or chest flap before reconstruction of the ear can be started (see Case 10 p 858) It is also possible to transplant the cartilage graft beneath the flap before the flap is transferred but the author advises against this since in his experience permanent impairment of circulation may occur in this part of the flap and graft It is safer to transplant the flap first and then to reconstruct the ear as outlined previously

ABSENCE OF HELIX

If the helix is absent usually owing to burns it is replaced with a tube flap from the lateral cervical region (Case 68 p 936) The tube is

Technic (Type 1. Restoration of Ridge of Anthelix) (Fig 238, Case 71, 72, pp 940, 941) On most points, the author follows the Davis-Kitlowski technic With the patient under general anesthesia the operative field is prepared in the usual way

The ear is now brought closer to the head by folding the unfolded portion of the anthelix upon itself, thus forming the ridge of the anthelix When the ear is in this position, the ridge of the anthelix is marked out



a *b*

Fig 238, *a* Protruding ears Restoration of ridge of anthelix (Davis, Kitlowski) Ridge of anthelix is marked out by series of punctures made with hypodermic needle dipped in aniline dye *b* Needle is pushed through ear Before withdrawing needle, it is touched with aniline dye to stain posterior surface of cartilage Lateral dotted line is line of punctures or posterior projection of ridge of anthelix The elliptical piece of skin to be excised is outlined by other dotted lines

on the anterior surface of the ear with one of the aniline dyes Then along the full length of this line a series of punctures is made in the following manner. A hypodermic needle is dipped in the aniline dye and placed at right angles to the anterior skin surface and thrust completely through the ear from front to back, coming out at a corresponding skin point on the posterior surface. When the needle emerges through the skin of the back of the ear, its point is touched with a toothpick swab

to leave the tube attached temporarily by a median bridge to the host area to safeguard its circulation (see p 90) (McNichols)

When the loss results from burns there may be in addition to the absent helix an adhesion between concha and mastoid region causing a backward tilt of the auricle. This deformity must be corrected by excision of the scar tissue reduction of the contracture and application of a skin graft as described previously before the tube flap is transferred.

In other cases, the helix is replaced with a local flap taken from the scalp The rim of the remnant of the ear is sutured to a scalp flap behind the ear In a second operation the flap is severed from the scalp (Case 66 p 934)

ABSENCE OF LOBE

Technic (Gavello) (Fig 237) A flap is used from the mastoid region with an anterior pedicle at the cheek. The flap which is one third larger than the defect, is outlined as shown in Fig 237 The posterior half *A*, is raised and returned to its original site. After two weeks the entire flap is raised and returned to its original site After two more weeks the entire flap is raised and folded upon itself so that the posterior half of the flap forms the median surface of the flap Its upper wound edge is sutured to the posterior wound edge of the defect the upper wound edge of the anterior flap to the anterior wound edge of the defect. The raw surface of the flap bed is closed either by undermining and skin sliding or by skin-grafting

Deformities

PROTRUDING EARS

Protrusion of the external ear is the commonest deformity of the auricle. It is usually congenital The base of the concha of a normal ear projects from the head in less than a 30-degree angle. The body of the concha then rounds forward until it reaches the anthelix Here the auricle bends sharply backward forming the ridge of the anthelix (Fig 234) In the majority of protruding ears the deformity is due to absence of this ridge (Type 1) The cartilage instead of folding backward to form the ridge is flat. The object in correcting the deformity in these cases must be the restoration of the ridge of the anthelix. The second and less common type of protrusion is of a different nature (Type 2) It is due to overdevelopment of the concha together with an increase of the angle between concha and head the anthelix being well developed. The object of reconstruction in these cases must be reduction of the size of the concha and reduction of the angle

must be divided. Sometimes, it is merely necessary to incise the cartilage along this line, at other times, excision of a small elliptical piece of cartilage is necessary, care being taken by the guiding finger on the anterior surface not to perforate the skin.

It is important to see that all cartilage spring is divided so that there will be no resistance or tension when the margins are turned in to form a supporting ridge. The cartilages are now folded over upon themselves to form the ridge of the anthelix. They are held together in this position by a Lembert type of suture. A cotton suture is passed through the perichondrium on one side, beginning about 0.5 cm ($\frac{3}{16}$ inch) from the cartilage margin, and coming out close to the margin. The needle is then carried across the defect and thrust into the perichondrium a similar distance from the margin and then out about 0.5 cm ($\frac{3}{16}$ inch) from the defect. Four or five of these sutures are placed but not tied. A Babcock clamp is placed on the anterior surface of the new ridge in front of the first suture, thus holding the folded cartilages rigidly together. The suture is now tied. Just before the knot is drawn tight, the clamp is removed. The other sutures are tied in a similar way. The skin is then closed with sutures. If, however, the skin is redundant, more skin is removed from the anterior wound edge. The skin sutures are on-end mattress sutures of 000 catgut, and the suturing should include the periosteum of the mastoid region. After they are tied, the skin edges are drawn into the sulcus of the ear. (If the periosteum is not included, the skin would drape like a tent over it.) The ends are cut short, the sutures usually bury themselves and do not need to be removed later on.

After-Treatment. The dressing is important. A piece of gauze and a narrow strip of sterile cotton are laid upon the wound. In front, all convolutions of the ear are packed with pieces of cotton or mechanic's waste. Then follows a piece of gauze on top, held in place with adhesive plaster. Over this is placed a firm head bandage. If possible, the dressing is allowed to remain in place for ten days. Another dressing is applied just over the posterior wound edges for one more week. The patient is then instructed to hold the ears close to the head at night for three months by an elastic skullcap.

Technic (Type 2. Reduction of Size of Concha and Reduction of Angle): The author follows Alexander's method. An incision is made at the posterior surface of the ear along the sulcus of the cephaloauricular angle. The skin is undermined on both sides and the lateral wound edge reflected aside, thus exposing the posterior surface of the cartilage. Depending upon the degree of deformity, the cartilage of the concha is incised from 6 to 8 mm. ($\frac{1}{4}$ to $\frac{5}{16}$ inch) laterally from its base in its

dipped in the same solution before it is drawn back again In this way sufficient dye is carried through the tissues to make the required marks on the cartilage.

An elliptical piece of skin is now excised from the posterior surface of the auricle. The vertical axis of this piece lies in the sulcus of the

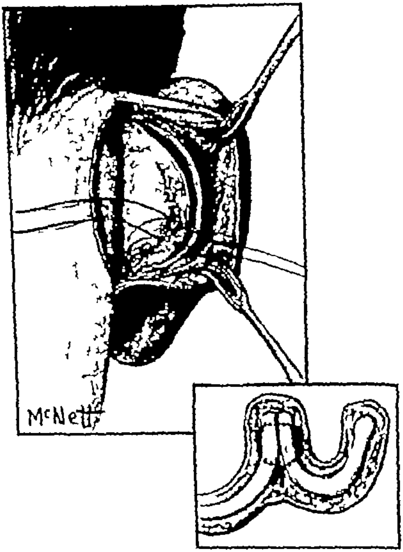


Fig. 238, c Lateral wound edge is undermined and reflected. Cartilage is divided along line of punctures. Cartilages are folded upon each other (insert) and held together with Lembert-type sutures.

cephaloauricular angle and should extend along the entire sulcus The greatest width should be about 1.5 cm (5/8 inch) if necessary more skin can be removed at the end of the operation.

The posterior surface of the cartilage is now exposed by undermining and reflecting the lateral wound edge When the cartilage is exposed a line of puncture points stained with the aniline dye can be seen in the cartilage itself This is the line along which the spring of the cartilage

full thickness of the helix and skin, with the base of the wedge the helix, to prevent later notching of the rim, the excision at the rim should be made staircase-like The wound edges of the helix and the remainder of the cartilaginous wound edges are now sutured together The anterior skin flap is trimmed to proper proportions and sutured to the skin edges of the helix Thus, the two excisions shorten the ear longitudinally and vertically The last step consists in trimming the wrinkles of the posterior skin to fit the new shape of the ear If the ears are not only enlarged but also protruding, protrusion can be overcome at the same time the ears are made smaller After reduction of size an incision is made along the proposed anthelix of the anterior surface of the ear cartilage, the cartilages are folded upon each other (compare with Fig 238 insert) and held in this position with a few mattress sutures The anterior skin flap is then draped over and sutured in place (Compare with Case 37, p 897)

CAULIFLOWER EARS

This deformity, as commonly seen in wrestlers, is due to the invasion of fibrous tissue by subcutaneous hematomas, the cartilage itself may increase in size and change the ear into a cauliflowerlike shape Operative correction consists in elevation of an anterior or posterior skin flap, excision of cicatricial tissue, shaping of the cartilage, and replacing of the skin flap The ear is now well padded and a pressure dressing applied

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entire length care being taken by the guiding finger on the anterior surface not to perforate the skin Now follows separation by blunt undermining of the anterior surface of the lateral part of the cartilage from the anterior skin covering This part of the cartilage is slid over and behind the median part of the cartilage and anchored in this position with sutures to the periosteum of the mastoid process The skin is now trimmed and sutured. There is some buckling of the skin at the anterior surface resulting from shortening of the concha. This as the author can confirm, flattens out in time For postoperative treatment, see the previous discussion under *After Treatment*

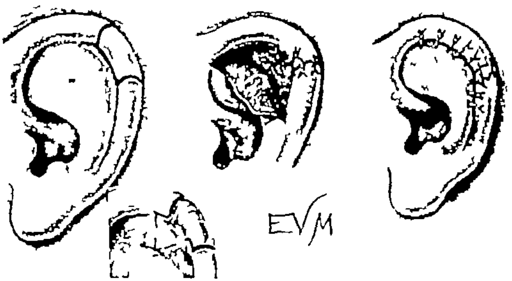

Fig. 239 *a* Reduction of large ears (Lexer) Excision of wedge-shaped piece of helix and anthelix in staircase-like manner outlined.
b Skin flap below helix is mobilized, wedge-shaped piece of helix, anthelix and posterior skin excised in staircase manner and wound edges sutured together.
c: Flap trimmed and sutured in place.

LARGE EARS

The external ear may only appear large or may actually be large. In the first type the appearance is caused by a protrusion of the auricle Correction of the protrusion as previously described, will correct the apparent enlargement. Genuinely large ears however need actual reduction

Technic (Lexer) (Fig 239) An anterior incision is made along the sulcus of the helix. A skin flap is dissected downward until the anthelix is reached This exposes the anterior surface of the fossa between helix and anthelix, leaving the posterior skin covering and that of the helix intact The next step consists in excision of a wedge-shaped piece of the

XII

THE OSSEOUS FRAMEWORK OF THE FACE

Defects

Of the defects of the facial bones, only the traumatic defects, comprising fractures and nonunions, will be considered here

FRACTURES OF MANDIBLE

Fractures of the mandible constitute the majority of fractures of the facial bones, for the mandible is exposed and poorly protected The injury—as a rule—is due to direct, less often to indirect, trauma.

Anatomy

The mandible, or lower jaw, consists of the body, which is convex anteriorly, and the two rami ascending from the two ends of the body (Fig 240)

Embryologically, the body consists of two halves, which unite in the midline, forming the symphysis It is the carrier of the teeth, which are supported by the alveolar process After loss of the teeth, this process disappears. The protuberantia mentalis forms the lower border of the symphysis, and is the most prominent part of the chin. The foramen mentale, a frequent site of fractures, is situated at the outside below the alveola of the second premolar It forms the exit of the canalis mandibulae, from which the nervus alveolaris inferior and vessels escape

Each ramus forms an angle of about 130 degrees with the body. Its lateral surface is roughened for the attachment of the masseter muscle. The center of the median surface contains the foramen mandibulare. This is the entrance of the canalis mandibulae, through which the nervus

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poralis, at the processus condyloideus, the musculus pterygoideus internus, at the median surface of the angle and ramus, and the musculus pterygoideus externus, at the neck of the processus condyloideus The *depressor* muscles are the musculus digastricus, the musculus geniohyoideus, the musculus genioglossus, and the musculus mylohyoideus

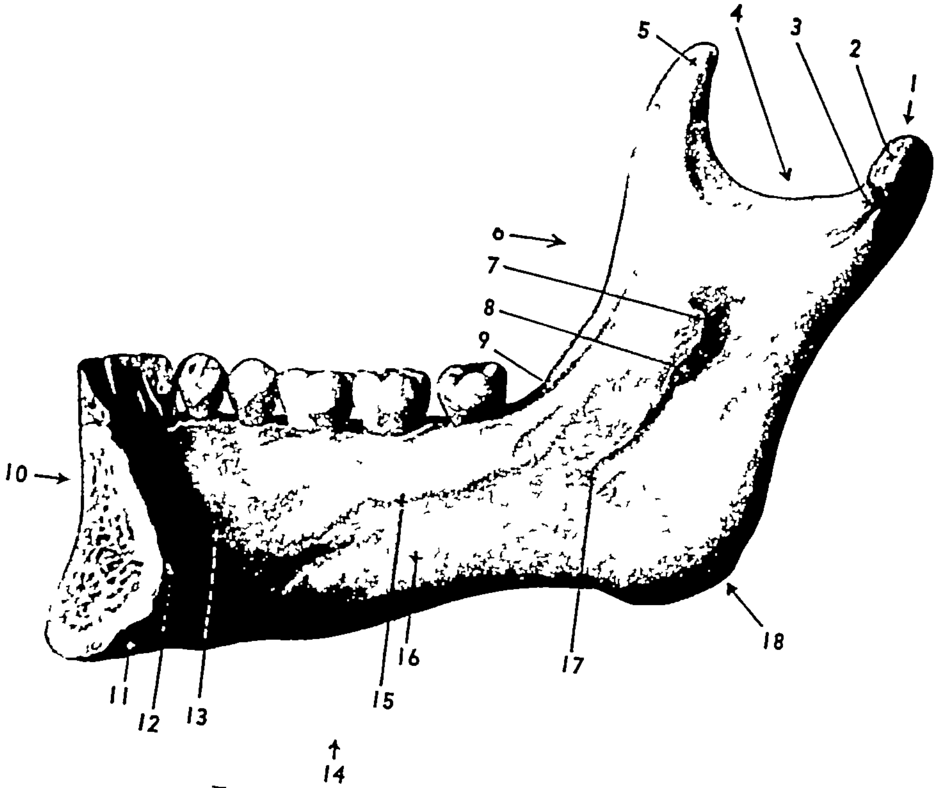

Fig 240, *b* Anatomy of mandible

1 Processus condyloideus
2 Capitulum
3 Fovea pterygoidea
4 Incisura mandibulae
5 Processus coronoideus
6 Ramus mandibuli
7 Lingula mandibulae
8 Foramen mandibulare
9 Crista buccinatoria
10 Pars alveolaris
11 Fossa digastrica
12 Spina mentalis
13 Fovea sublingualis
14 Corpus mandibulae
15 Linea mylohyoidea
16 Fovea submaxillaris
17 Sulcus mylohyoideus
18 Angulus mandibulae

(W Spalteholz Handatlas der Anatomie der Menschen S Hirzel, Leipzig)

They all arise from the lingual or inner surface of the body, and form the floor of the mouth

Symptoms, Signs, and Diagnosis

The patient with a fracture of the mandible is—as a rule—unable to open and close the mouth to a normal extent, owing to the interruption

alveolaris inferior and vessels pass The upper end of the ramus carries two processes which are separated by an incisure. The anterior process is called the processus coronoideus, which is the inserting point for the musculus temporalis the posterior process, the processus condyloideus, carries the capitulum mandibulae which forms the lower half of the

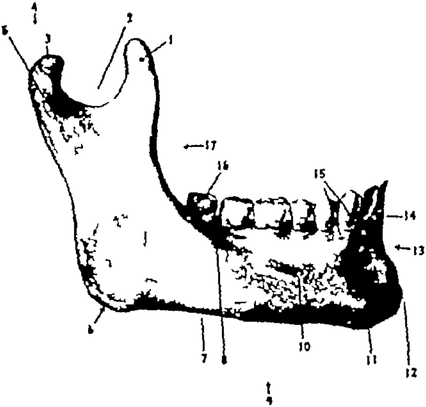

Fig. 240, a: Anatomy of mandible

1 Processus coronoideus
2: Incisura mandibulae
3 Capitulum
4: Processus condyloideus
5: Collum
6: Angulus mandibulae
7 Basis mandibuli
8: Linea obliqua
9: Corpus mandibulae
10 Foramen mentale
11: Tuberculum mentale
12: Protuberantia mentalis
13: Pars alveolaris
14 Limbus alveolaris
15: Juga alveolaria
16: Crista buccinatoria
17 Ramus mandibuli

(W Spalteholz Handatlas der Anatomie der Menschen. S. Hirzel, Leipzig.)

mandibular joint Below the capitulum is a constriction called the "collum mandibulae a frequent site of fractures.

The muscles inserting at the mandible can be divided roughly into elevators and depressors The *elevator* group consists of the musculus masseter the musculus temporalis, and the musculi pterygoideus internus and externus This group inserts at the angle and the ramus of the mandible the musculus masseter at the lateral surface the musculus tem

should be thoroughly cleansed with hydrogen peroxide. If the fracture line runs through the socket of a tooth, the latter should be removed unless loss of the tooth would increase the displacement of the fragments and make reduction difficult. The best example is a fracture in front of the last molar tooth. Loss of this tooth would favor upward displacement

Fig 241 Emergency dressing for fractured mandible, similar to Barton bandage. Anterior part of chin should not be included in dressing to avoid posterior displacement

of the posterior fragment In such a case, the tooth should be left in place for about ten to fourteen days or even much longer, the fixation is then temporarily removed and the tooth carefully lifted out of its socket

Reduction of Fragments: Reduction of the fragments may require anesthesia. General anesthesia should be avoided if possible Local anesthesia, either as block anesthesia of the nervus alveolaris inferior or as

of the continuity of the bone and to pain Bleeding from a tear of the mucous membrane swelling and tenderness over the injured place are seldom missing Abnormal motility malocclusion and deformity if present confirm the diagnosis.

Fractures of Symphysis If the fracture line runs through the midline, a deformity may be absent. If there is marked comminution however and a loss of bone, a considerable narrowing of the mandibular arch may be the consequence

Fractures of Mandibular Body The commonest fracture runs through the region of the foramen mentale The anterior fragment is displaced downward owing to pull of the depressor muscles the posterior fragment is pulled upward and outward owing to action of the elevator group There may be a deviation of the chin toward the fractured side

Fractures of Ascending Ramus Processus Condyloideus, and Processus Coronoideus The displacement of the fragments of the ramus is slight the deformity may consist only in a deviation of the chin toward the fractured side. In the majority of fractures of the processus condyloideus a deformity is not noticeable Fractures of the processus coronoideus are rare and without visible displacement.

Double Fractures The commonest fracture runs through the foramen mentale on one side and through the angle on the other side The anterior fragment (chin fragment) is displaced downward and backward owing to the pull of the lingual muscles the posterior fragments are pulled upward by the elevators

While in the majority of cases the clinical diagnosis of fracture of the mandible is obvious the exact location and form of the fragments however can be defined only by x ray examination X ray pictures should be taken from two planes should possibly be three dimensional and must include the entire jaw together with the condyles.

Treatment

Therapy may be primarily an emergency treatment followed by a final treatment. In a simple fracture of the mandible the *emergency* treatment simply consists in the use of a head bandage such as shown in Fig 241 No turn should go around the anterior surface of the chin which would inevitably increase the displacement. Such a bandage achieves sufficient temporary immobilization to keep the patient comfortable until final treatment can be undertaken The emergency treatment of compound fractures of the jaw has been discussed on p 109

The *final* treatment consists in reduction of the fragments and in retention Certain preliminary steps however are necessary The mouth

a pair of these teeth until only the eyelet is visible buccally, the ends lying lingually Each end of the wire is now passed around the neck of the adjacent tooth so that both ends emerge on the vestibular aspect (Fig 243, *above*) One end of the wire is threaded through the eyelet lying between the teeth (Fig 243, *below*) Each free end is now grasped with a hemostat and pulled snugly around the necks of the teeth Then the

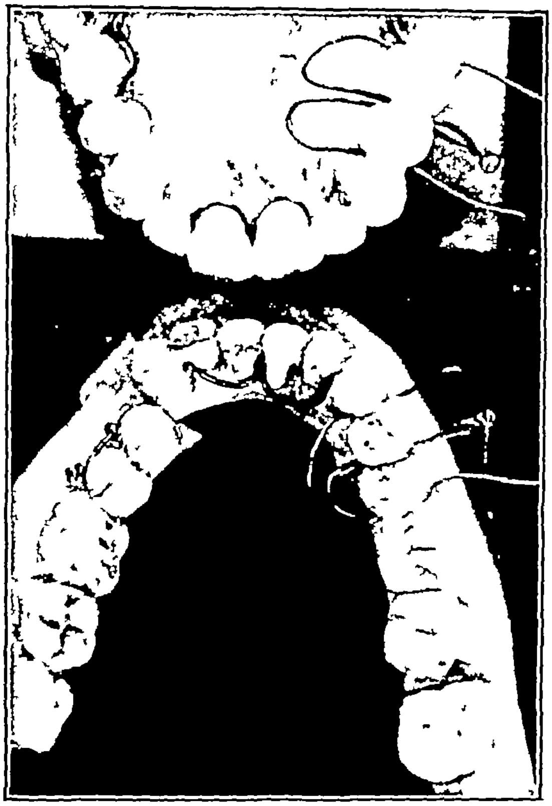

Fig 243 (R. H Ivy and L Curtis Fractures of the Jaws Lea & Febiger)

wires are twisted as tightly as possible All twists should be made in one direction, so that one will know how to tighten the wires should it become necessary later The ends are cut short and bent against the teeth. The same procedure is undertaken at the other selected pairs of teeth Thus, three points of attachment are prepared Through each of the three pairs of eyelets is passed a single strand, 30 5 cm (12 inches) long, of the same No 24-gauge brass wire (Fig 244) The patient is now instructed to bring the teeth together while an assistant, with the palms of both hands beneath and around the mandible, aids in reducing the fragments The corresponding ends of the wires are now twisted, and the ends are cut short and turned away from cheeks and lips Some tightening of the wires may be necessary after twenty-four hours

infiltration anesthesia is the method of choice. If general anesthesia must be used the intravenous injection of sodium pentothal is preferable The object of reduction is to achieve a normal occlusion of lower and upper teeth if they are present. In edentulous jaws however, a proper alignment of the fragments is more difficult to obtain

Immobilization The object of immobilization is to retain the reduced fragments in position until healing has occurred This is best achieved by using the upper jaw as a splint and fastening the teeth of the lower

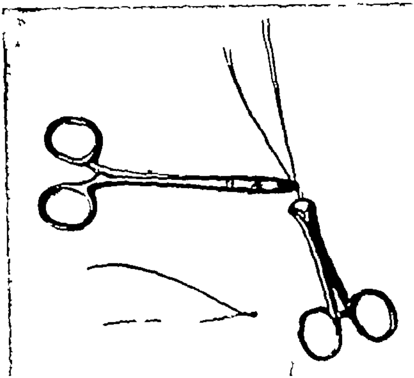

Fig. 242: Making eyelet in No. 24 gauge soft brass wire. The wire, 15.2 cm (6 inches) long, is folded at its middle around towel clamp. Two twists are made with hemostat.

jaw to those of the upper jaw with wires If teeth are missing, the problem of immobilization becomes more difficult.

Interdental Wiring Many methods have been described The author prefers the eyelet wire method that has been described by Ivy and Curtis, and follows their technic throughout.

The wire used for the procedure is No 24-gauge of soft brass A wire, 15.2 cm (6 inches) long is folded at its middle around a towel clamp and two twists are made with a hemostat to form a small eyelet (Fig 242) The teeth usually selected for attaching the wires are the premolars above and below on each side and the incisors in front or other opposing teeth if the aforementioned are absent. Both ends of the eyelet wire are inserted from the vestibular aspect through the interproximal space of

In cases of fracture with considerable displacement, it is advisable to place a separate half-round wire arch on the teeth of each segment until complete reduction has been obtained and then to replace the separate arch wires by a single arch (Fig 246)

In cases of marked displacement, gradual reduction can be obtained by elastic traction on individual segments by means of small orthodontic rubber bands passed over the ends of the twists of the brass wires, these

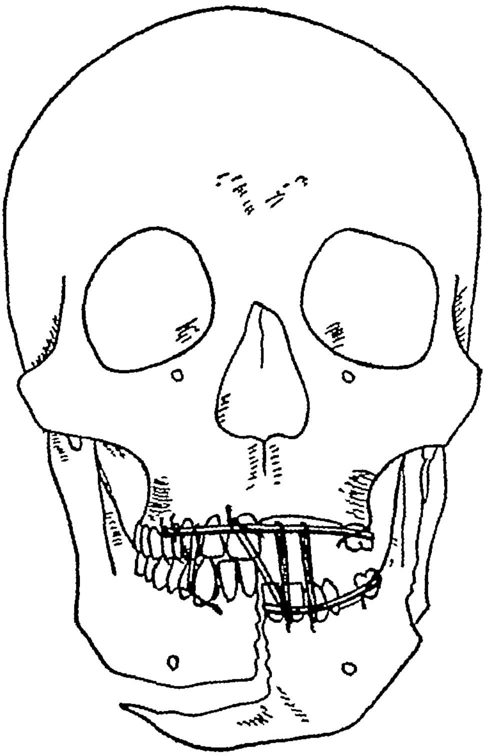

Fig 246 (R H Ivy and L Curtis Fractures of the Jaws Lea & Febiger)

elastics running in the desired direction of pull from the lower to the upper arch (Fig 246). When reduction has been completed, the rubber bands can be replaced with No. 24-gauge brass tie wires

If reduction of the fragments cannot be accomplished by the closed method, one should not hesitate to resort to open reduction and fixation of the fragments with bone sutures of thin stainless steel wires This is followed by immobilization of the fragments with interdental wiring or with the arch-wire method

In simple transverse fractures, particularly those without much displacement of the fragments, internal fixation by means of a Kirschner-type wire, drilled from a small skin incision through the longitudinal axis of the fragments, as recommended by J B Brown and F McDowell, is a simple and effective method (Figs. 248 and 260). The end of the

Alternative Method When the teeth are not sufficient in number and stability for direct application of the eyelet wires Ivy and Curtis recommend the following method A plain German silver half round arch wire is molded to conform to the vestibular surfaces of the lower teeth and curved so as to pass accurately well around the distal surface of the poste

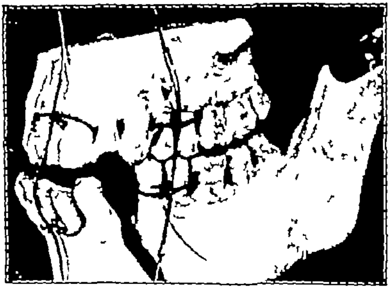

Fig. 244: (R. H Ivy and L. Curtis Fractures of the Jaws, Lea & Febiger)

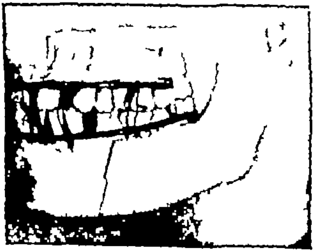

Fig. 245 (R. H. Ivy and L. Curtis: Fractures of the Jaws, Lea & Febiger)

rior tooth The arches are attached to the teeth with brass wire ligatures In cases of instability an additional circumferential wire may be passed around the arch and the mandibular bones A similar arch is applied to the upper teeth and then the upper and lower arches are connected by the finer brass tie wires (Fig 245)

In unilateral cases, this method has the disadvantage of requiring an incision and drilling a hole through the angle of the jaw on the sound side Ivy and Curtis simplified the procedure in unilateral cases by connecting the wire coming from the angle of the jaw by means of heavy elastic bands to a hook on a plaster-of-paris headcap (Fig 247) (For construction of headcap, see p 429)

Fig 247 Wire traction in fractures of mandible with long edentulous posterior fragment

For the majority of cases, however, open reduction and fixation of the fragments with bone sutures of thin stainless steel wire is a simpler and more effective procedure This is followed by immobilization of the fragments by means of interdental wiring Intramedullary wire fixation (see p 418) will not be applicable, as a rule, owing to the obliquity of the fragments Extraoral skeletal pin fixation (see p 422) may be considered

Fractures through Angle of Mandible These fractures are often impacted, requiring no special treatment Otherwise, open reduction and fixation of the fragments with a bone suture of thin stainless steel wire or insertion of an intramedullary wire (Fig 248, *a* to *d*) may be indicated If the former method is used, additional immobilization of the fragments by means of interdental wiring is usually required

wire is buried beneath the skin Additional fixation is unnecessary The wire is removed after healing has taken place

Interdental wiring is also effective in fractures through the neck of the condyle Open reduction is hardly ever necessary It has frequently been stated that this fracture if the condyle becomes displaced is followed by ankylosis or deformity unless open reduction is performed Ivy Curtis and MacLennan however who base their recommendation on great experience treat the fractures at the neck of the condyle, with or without displacement of the head fragment by the usual methods of wiring the teeth in occlusion and have invariably had good results The author also agrees with J B Brown that in a number of cases the fracture is oblique with the posterior obliquity at the head fragment thus preventing a forward displacement of the latter

Cleansing, Feeding, Duration of Immobilization A simple and effective way of cleansing the teeth and mouth is by application of hydrogen peroxide in any of the ordinary antiseptic mouthwashes The vestibular surface of the teeth is cleaned with an applicator while the lingual surface is taken care of by the patient himself by the use of his tongue and the same solution

Feeding, as a rule, is possible by drinking tube a liquid or semisoft high caloric, vitamin rich diet is essential Rarely and then only during the first few days after the trauma, feeding through a nasal catheter may be resorted to

The fragments must remain immobilized until sufficient callus has formed which in a simple fracture usually occurs between three and six weeks.

TREATMENT IN SPECIAL CASES

Fractures with Long Edentulous Posterior Fragments In such a case the posterior fragment owing to lack of opposition is displaced upward by the pull of the elevator muscles To counteract the pull Darcissac advises direct downward traction by means of wire drilled through the angles of the mandible that is, through the angles of the posterior fragments A small incision is made along the posterior aspect of the angle the latter is exposed a hole is drilled and a No 24-gauge brass wire passed through it The wire is tightened the long end of it emerges through the wound the latter is now closed The same procedure is performed on the other side Both wires are now led around the back of the neck and connected with each other over a heavy gauze pad. The other anterior fragment is now fastened to the upper teeth by interdental wiring

and wire are now withdrawn, and the wire is disengaged. The instrument is reinserted, this time along the anterior surface of the bone until the tip can be pushed through the same small incision The other end of the wire loop is now engaged into the instrument and the latter withdrawn Using the same entrance allows the wire loop to rest on the bone with no skin between, conducting the wire in the direction described makes its twist lie inside the mouth, facilitating later removal. The same procedure is performed around the other fragment The fracture is now reduced, the vulcanite splint is placed upon the alveolar ridge bridging the line of fracture, and the wires are twisted tightly upon the splint

In some cases, intramedullary fixation (see p 418) may be a simpler and more effective method of stabilization of the fragments (Fig 248, *a* to *d*) On the other hand, insertion of the wires may be more difficult than had been anticipated If this is the case, the following method should be applied

Extraoral Skeletal Pin Fixation The indications for extraoral skeletal fixation are—according to Thoma—as follows if a patient, as in wartime, has to be transported, if there is an insufficient number of teeth for interdental fixation, if many teeth are broken or loose, unsuitable for wiring or splinting, if jaws are edentulous, if there is displacement of an edentulous posterior fragment, if there are multiple fractures, if the jaw is to be stabilized when large parts of bone have been lost, if compound fractures are associated with extensive wounds; if bone-grafting is indicated, if bone infection or dental infection is present, or if there are wounds which require irrigation and other local treatment.

The underlying principle is that of the dual transfixation of each fragment (after Roger Anderson, Converse and Waknitz, Stroub and others). Under anesthesia with intravenous sodium pentothal, endotracheal nitrous oxide and oxygen, or ether, and under aseptic precautions, two pins of medium-sized wire are inserted with a hand drill at an angle of about 75 degrees to each other at an elected position of one of the fragments The pins must penetrate the outer cortex and also slightly the inner cortex An assistant, not belonging to the aseptic operating team, steadies the fragment from the oral side A pin clamp with a universal joint is slipped over each pin; a rod of proper size and length is slipped through the pin clamps and fastened by tightening the screw of the joint The rod should project 1 2 cm. (½ inch) toward the fracture side The same procedure is performed at the other fragment Double universal-movement clamps are now slipped over the contiguous ends of the rods. The fracture is now reduced; a fixation rod is slipped through the double universal-movement clamp and locked by tightening the screws

Fractures of Edentulous or Almost Edentulous Mandible. If the fragments are displaced, circumferential wiring of the mandibular bone (G V Black) over a vulcanite splint (Ivy and Curtis) provides sufficient stability A vulcanite splint is first made like a saddle to cover the alveo-

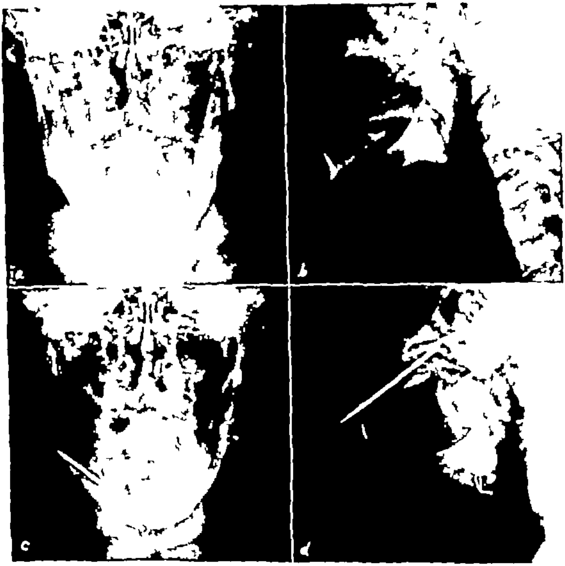

Fig 248, a-d Bilateral fracture of mandible; left side stabilized with intramedullary wire; fracture through angle of right side fastened with wire suture.

lar ridge on each side of the fracture In some cases the patient's denture may serve as the splint.

From the lingual (posterior) side of the mandible, a curved suture carrier (Fig 262) is led along the posterior surface of the bone in close contact with the latter until the tip is felt beneath the skin of the chin. A small incision is made at this point, the instrument pushed through the opening and then armed with No 24-gauge brass wire. Instrument

ciples do not differ from those for bone-grafting in other regions absence of infection for at least six months (preoperative and postoperative administration of antibiotics), presence of sufficient skin covering, removal of all scar tissue—particularly of all atrophic and sclerotic bone tissue—and prolonged immobilization Immobilization, when enough upper and lower teeth are present, is not difficult to obtain, but may become a problem in edentulous or almost edentulous jaws Hence, the problem of immobilization should be of primary concern and be solved preoperatively

Preoperative Preparation for Immobilization · If interdental wiring is possible, the arch-wire method (see p 417) should be used, since it guarantees better stabilization than the eyelet method

The arch wires should be applied preoperatively, but upper and lower teeth should not be connected with each other until the patient is well out of anesthesia. In edentulous or almost edentulous jaws, special splints should be made of acrylic resin or other substance, fitting the upper and lower jaws and providing a feeding space, the splint is kept in place by supporting the lower jaw with a head bandage Extraoral skeletal pin fixation (see p 422) may be the method of choice in certain cases In any case, the ingenuity and collaboration of a skillful dental colleague are paramount

Preoperative preparation for immobilization may be unnecessary if Nichol's method of fixation of the fragments with metal bone splints is possible (p 636)

Choice of Graft The proper selection of the various types of grafts depends upon the location and size of the defect Available are grafts from the anterior surface of the tibia, crest of the ilium, and occasionally a section of a rib Iliac cancellous bone chip grafts have been introduced by Mowlem Since then, cancellous bone from the crest of the ilium, either in blocks or combined with bone chips, have been found widely successful The author prefers a massive graft from the crest of the ilium from which much of the cortical substance is removed Such a graft is useful for filling the majority of mandibular defects In cases where the ascending ramus must be replaced together with the condylar head, the fifth metatarsal bone with its articular surface is used (Fig 250) If the fifth metatarsal is too short to fill the defect, a piece of the eighth or ninth rib with a thin cartilaginous attachment is used, the latter replaces the condyle, and the curved part of the rib replaces the angle of the mandible The graft should be transplanted with its periosteum In still larger defects, bone grafts may not be available If this is the case, one may use vitallium prostheses (recommended by Conley) or a stainless

of the latter In double fractures, one unit on each side is necessary for proper stability and fixation of an additional cross-bar which unites the two units (Fig 249)

This method has the advantage of satisfactory immobilization and it permits the use of the mandible. It also allows subsequent improvement of the position of the fragments if necessary since the universal movement clamps may be unlocked and the fixation rod adjusted.

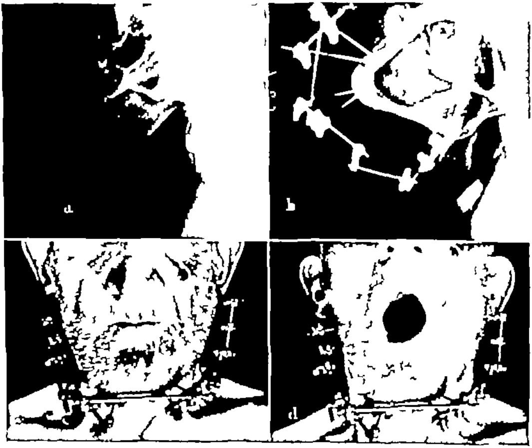

Fig. 249: Double fracture of an edentulous mandible. After reduction of the fragments, extraoral skeletal pin fixation was applied.

Nonunions and Bone Defects Nonunions of the mandible, as with nonunions in general are due to absence or lack of stimulation of the local osteogenetic forces. Bone defects are due to infection destruction or tumors of the mandible

In these cases, the treatment consists in bone-grafting as first recommended by Sykoff (1900) whose technic was improved and standardized by Lexer Garrè Payer Lindemann Gillies Risdon Ivy and Epes, Blocker and Weiss Stout, Macomber and others Ivy has presented a collective review of the literature on this subject up to 1951 The prin

a thin stainless-steel wire through each hole, and twisting the wires upon the graft The wires are cut short and bent backward

In *end-to-end coaptation of graft and fragments,* Nichol's method of fixation of graft and fragments with metal bone splints may be possible (p 636)

In *large defects,* as in the anterior section of the mandible, the ends of the host bone are shaped in such a way as to present a broad transverse section of bleeding healthy bone A bone graft is removed from the crest

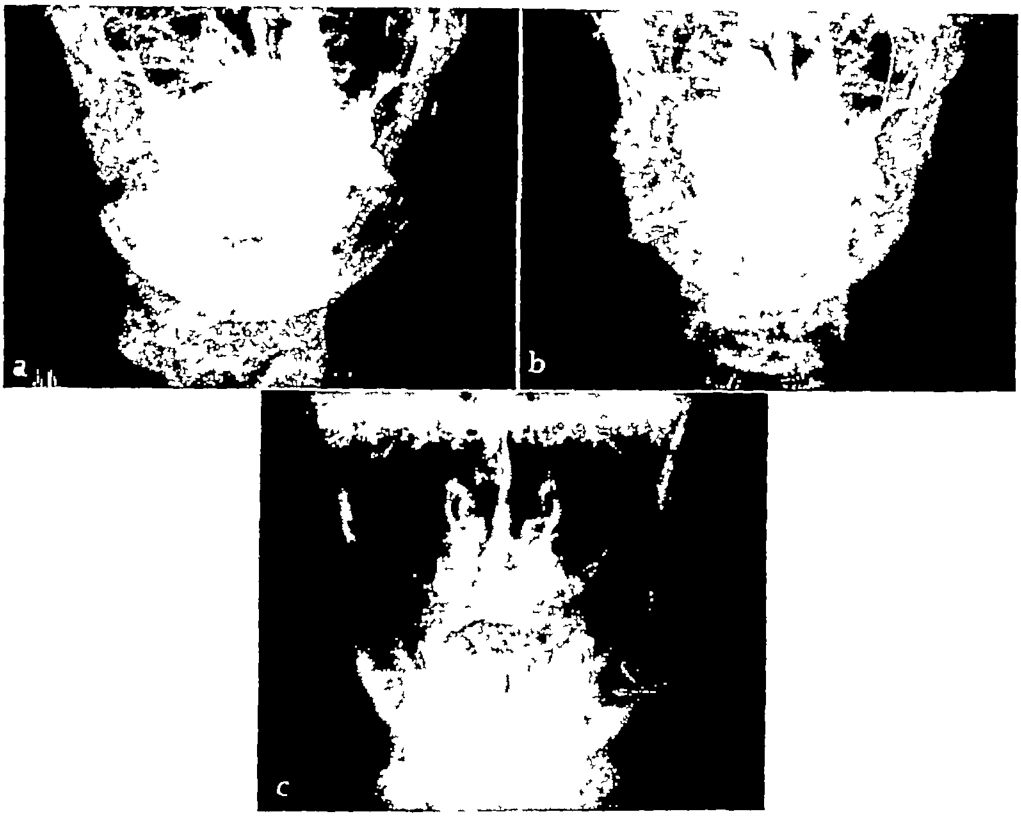

Fig 251, *a* Bone defect after sequestrotomy (osteomyelitis) *b, c* Eight months and ten years after insertion of periosteum covered bone graft. Immobilization of jaws by interdental wiring for three months

of the ilium (Fig 34), and shaped to fit snugly into the defect To afford better stability in these large defects, it is advisable not to remove the cortical part of the ilium graft. A transverse canal is drilled through the end of each fragment and each end of the graft. A thin stainless-steel wire is threaded through the corresponding canals, twisted, and cut short Then follows closure of the soft tissues in layers

In cases where the oral cavity has had to be opened temporarily—for instance, after resection of large mandibular tumors—Marino et al, Edgerton et al, Castio et al (mentioned by Ivy), and Conley have reported success after immediate correction of the defect with a bone graft

steel mesh prosthesis (by Abbie et al) or an acrylic implant (after Healy et al)

Technic (Fig 251) From a curved incision (curved posteriorly) below the mandible the bone fragments are exposed. All scar tissue is removed and—no matter how large the resulting defect—all atrophic and sclerotic bone ought to be resected until bleeding bone is encountered Care is taken not to perforate the buccal mucous membrane If this happens the operation must be terminated

Fig. 250 Loss of left ascending ramus of mandible replaced with fifth metatarsal bone (including articular head) Immobilization of edentulous jaws with a splint of acrylic resin, fitting to upper and lower jaws and providing feeding space Bony union after 3 months with full function.

The fragments to receive the bone graft are prepared in one of two ways either by the staircaselike method (Fig 251) or by effecting a broad transverse section In small defects only the former method is suitable while the fragments of large defects can be prepared in either way

In the *staircaselike method,* the periosteum is elevated from the outer lower borders of the bone stump to form a pocket with a bone rongeur the lower cortex of the bone is removed for a distance of from 1 to 2 cm (3/8 to 13/10 inch) until the medullary cavity is exposed. A bone graft is removed from the crest of the ilium as demonstrated in Fig 34 It is advisable to remove all cortical bone to obtain a cancellous-bone graft, since cancellous bone regenerates quicker than cortical bone. The cancellous graft is now separated and fitted into the prepared graft bed. All cancellous fragments should be saved so that they can be packed later into the dead spaces of the graft bed. Although the periosteal pockets of the host bone may hold the graft in place the author prefers additional wiring by drilling transverse canals through the end of each fragment, feeding

It may be safer however to bridge the gap with a temporary prosthesis until healing has taken place thus preventing shortening of the mandible from contracture Freeman uses vitallium plates. Byar's method of insertion of a bar of stainless steel is simpler and just as effective (Fig 252) Drill holes are made in the most dense part of the bone ends and a thick Kirschner wire is snugly inserted into them If possible the bar should be inserted so that the ends contained in the bone are slightly bent. Thus the stress is distributed so that the metal ends stop boring through the rather soft bone

Fig. 252 Defect of horizontal ramus of left side of mandible after radical resection of cancer of floor of mouth. Temporary stabilization of fragments by insertion of stainless steel bar inserted into drill hole of end of each fragment.

Time of Immobilization The grafted mandible should be immobilized until an organic union has formed between host bone and graft, which—as a rule—occurs after the third month

FRACTURES OF MAXILLA

These fractures may involve the body of the maxilla or may be complicated involving in addition the facial bones such as the zygoma nasal bones and septum. They may be unilateral or bilateral They are as a rule due to direct trauma and in most instances are compound fractures.

Fractures of Alveolar Process

These fractures either are due to direct hits or occur in the extraction of teeth As a rule they can be easily reduced by manipulation and held

2 Mastoid region As close as possible to the ears but not encroaching on them

3 Temporal region To about the zygomatic arch Definitely below parietal eminences

4 Frontal region Care must be exercised in freeing forehead to about 1 inch above eyebrow line

Fig 255

Fig 256

(R H Ivy and L Curtis Fractures of the Jaws Lea & Febiger)

Fig 257

(R H Ivy and L Curtis Fractures of the Jaws Lea & Febiger)

CONSTRUCTION STEPS 1 Seat patient in straight-backed chair without headrest

2 Clip hair on men if the case is to require lengthy fixation (two or more months)—otherwise not considered necessary Have women braid hair and arrange in loose coil on top of head

3. Apply one end of stockinette over head to a point 2 inches below previously determined border outline of finished headcap (Fig 253)

tion The latter method should be chosen whenever possible since it eliminates the use of an objectionable headgear

Plaster of Paris Headcap (Figs 253–257) Materials necessary for construction

1 Stockinette (3 inches by 2 feet) Three inch stockinette is 6 inches in circumference and capable of considerable stretching If not available any substitute may be used, such as a leg from a pair of balbriggan drawers or a heavy white stocking

2 Narrow gauze bandage or tape (1 foot long)

Fig. 253

Fig. 254

(R. H. Ivy and L. Curtis: Fractures of the Jaws. Lea & Febiger)

3 Adhesive plaster (1 inch wide)

4 Orthopedic felt (four or more strips—1½ inches by 6 inches) If not available use strips of heavy cotton batting or several layers from an old felt hat.

5 Plaster-of paris bandage (2½ inches by 10 feet) Two of these are necessary

6 Plaster of paris (good quality model plaster) Large plaster bowl and heavy spatula

7 Traction appliances Leather straps and buckles, hooks, loops, webbing etc., as indicated. Hooks can very conveniently be made from an ordinary wire coathanger

8 Scissors Bandage scissors for felt, small scissors for other materials.

OUTLINE OF HEAD AREAS TO BE UTILIZED The direction of stress must necessarily determine the anchorage area. In general the finished margins of the cast should extend

1 Occipital region Well over the external occipital protuberance toward the base of the skull.

and two or three ligature wires (If the teeth are missing, the dental plate can be used instead.) A plaster-of-paris headcap is made in which hooks are incorporated The bars of the tray are now connected with the hooks by elastics, providing traction in the desired direction This dressing remains in place for three weeks, it is then replaced by inter-

Fig 259 Patient with bilateral horizontal fracture of maxilla, nose, and floor of orbits After reduction of fragments, immobilization is achieved with wire-suspension method, after Federspiel (see text) (See Case 51, p 916)

dental wiring and a comfortably fitting head bandage. The average time for union to take place is six weeks.

Wire-Suspension Method (Federspiel) (Fig 259): A half-round arch wire is fastened to the teeth of the upper jaw with brass tie wire To overcome downward displacement, a No 24-gauge brass tie-wire loop is fastened to the arch in the premolar region on each side. The ends of the

4 Tie narrow bandage or tape loosely around stockinette at top of head so that the loop will be about 2 inches in diameter

5 Cut slit in stockinette and push tied ends of tape through to inside. This is done so that stockinette may be tightened during later treatment if necessary

6 Cut and adjust felt strips one (or more) in each quadrant and fasten in place on stockinette with adhesive plaster

7 Pull free end of stockinette down over head and trim just short of the length of the first layer Felt strips are now between layers of stockinette There is a small opening at top of head in which the ends of the cord are found (Fig 254)

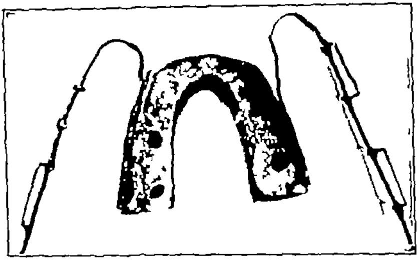

Fig. 258: (R. H Ivy and L. Curtis Fractures of the Jaws. Lea & Febiger)

8 Apply first plaster bandage Wet bandage in lukewarm water and apply as a head bandage over stockinette keep bandage wet and smooth into place with wet hands being certain to obtain desired outline form (Fig 255)

9 Apply plaster wash over this layer smoothing well with wet hands

10 Turn up both ends of stockinette to form the lower border of cap plastering the stockinette into plaster wash.

11 Insert traction appliances as indicated for case i.e., straps hooks, loops, etc These must be so placed as to deliver the correct directional force for the individual case (Fig 256)

12 Apply second plaster bandage in same manner as before except that the lower ½ inch of stockinette is left exposed to produce a smooth rounded border that will not cause irritation or crack during extended usage (Fig 257)

13 Apply second plaster wash—smooth well with wet hands. After allowing to dry thoroughly the headcap can be varnished if desired.

Dental Tray Method (Ivy Curtis) (Fig 258) To a metal impression tray are soldered heavy wire arms in such a position that they emerge at the corners of the mouth passing back for a distance in front of both cheeks The tray is secured to the teeth by dental impression compound

through the infraorbital ridge The wire is then threaded through the opening, looped over the ridge, and both ends are passed together along the anterior wall of the antrum into the upper sulcus over the second molar teeth where they are caught with a hemostat The fractured bone is then elevated to its normal position, and the wires are drawn taut and fixed to one or more of the teeth (If the patient is edentulous, see foregoing paragraph)

If removal of the wires becomes necessary, the loop should be cut at the orbital rim and the wires withdrawn from below

If the fracture is badly comminuted (Fig 260), the fragments are brought together in alignment It is best to use the lower jaw as a guide to check proper occlusion If the mandible is also fractured, it should be fixed first The maxillary fragments are held together with an arch wire The unit is then suspended as described above

If the infraorbital rim is also fractured, as in associated fractures of the zygoma and malar process, the drill hole is made lateral just above the zygomatic frontal suture line

In bilateral fractures with extensive communications, upward suspension would shorten and distort the face One may combine internal-wire fixation and the insertion of Foley catheters into the maxillary sinuses (see p 436) to control the level of the fragments, which should be in proper occlusion with the lower jaw If the dental tray is used, it is fastened to the upper teeth, but instead of elastic upper traction, the dental splint must be suspended rigidly at the proper distance from the skullcap by means of solid vertical rods or bars Brown et al advise fixation of the loose fragments to solid bone by inserting several Kirschner wires (see p 436)

FRACTURES OF MALAR BONE AND ZYGOMATIC ARCH

These fractures are due to direct trauma While the body of the malar bone seldom breaks, since it is strong, its processes are frequently fractured The body may become separated from all its attachments (frontal, orbital, maxillary, and zygomatic processes) and depressed The cheek—after the initial swelling has disappeared—is found depressed just below the lateral canthus of the eye, while lower down it may appear swollen Treatment consists in elevation of the malar bone and restoration of the zygomatic arch as soon as possible. Gillies and Killner's method is simple and effective

Technic (Fig 261) The hair is shaved in the corresponding temporal region From a small incision, 2 5 cm (1 inch) above and anterior to the upper attachment of the ear within the hairline of the temporal

wire are now threaded on a long straight needle and passed through the cheeks along the lateral surface of the zygoma, emerging through the skin at the zygomatic level A plaster-of paris skullcap is made in which hooks are incorporated. The wires are fastened to the hooks and can be tightened daily until reduction is achieved After treatment is the same as previously described.

If the teeth are missing the dental plate can be used for fixation provided it is intact otherwise dental wax may be molded around the

Fig. 260, *a*. Multiple fractures (4 fragments, no loss of teeth!) of maxilla; separation of fragments from orbital floor Fracture of mandible.

b Fragments of maxilla gathered and held together with half round arch wire. Maxilla suspended with a wire loop through hole in right orbital rim. Insertion of intramedullary wire for stabilization of fracture of mandible. (Compare with Case 42, p. 904.)

alveolar ridge and over the hard palate the wires are drawn across the palate and tied in the midline the ends are embedded in the wax. Brown et al drill a strong Kirschner wire from one cheek through the maxilla and out the other cheek. The maxilla is then suspended on this wire to the skullcap

Internal Wiring Fixation (W M Adams) (Fig 260) By this method the cumbersome headgear is eliminated. The downward displaced maxillary fragment is held suspended by means of one or two wires fastened to the orbital rims (Fig 260) In a simple bilateral fracture of the maxilla a small incision is made over the infraorbital ridge on either side A hole of sufficient size to accommodate a No 25 stainless steel wire is brought

achieved by packing the antrum or by the internal wire-pin fixation. For packing the antrum, iodoform gauze with balsam of Peru on it has been recommended The author, however, favors a water-inflated balloon (rubber-glove finger on a No 14 catheter after Johnson or a Foley catheter after Oakey), this is a more versatile method and permits adequate drainage, hence, elevation of the fragments can be carried out over a period of weeks instead of days

Technic (Use of Foley Catheter after Oakey): From an incision in the gingivobuccal fold above the second molar, a hole in the antrum is made with a chisel in the same manner as in the Caldwell-Luck procedure If the fragments are badly impacted and cannot be elevated from the outside (by a pull or hook which is inserted beneath the zygoma or the orbital rim if the latter is depressed), reduction is aided by direct push with elevators from the antrum A No 20 to 24 Foley catheter is now selected; its tip is cut off and also part of the main tubing, except for the small tube which leads into the balloon part The catheter is inserted through the hole in the antrum and gradually inflated When this is done, the position of the fragments must be controlled by outside molding, this includes the canthal region when the orbital borders are replaced. One word of caution When the fragments are loose, there is more danger from over- than undercorrection

Technic (Internal Wire-Pin Fixation after Brown, Fryer, McDowell): This method consists in stabilization of the fragments with a regular Kirschner wire, which is drilled from a solid area into the loose fragment In comminuted fractures, it may be drilled through loose fragments without such a support, since there is the advantage of holding the fragments together. Before the wire or wires are inserted, the fragments must be reduced, as outlined in the foregoing technic The exposed end or ends of the wire are covered with adhesive or corks

After-Treatment: Through postoperative x-ray films, the position of the fragments is checked If a Foley catheter has been used and reduction of the fragments is found over- or undercorrected, further correction can be easily accomplished by inflating or deflating the balloon, this cannot be done after internal-wire fixation without removing the wire Elevation is maintained for three weeks, the balloon is then deflated, if the fragments remain in place, the catheter is removed, the hole in the maxilla closes quickly With internal-wire fixation, it is safer to leave the wire in place for at least four weeks

FRACTURES OF NASAL BONES

Fractures of the nasal bones are due to direct trauma The resulting displacement of the fragments is in the line of force.

region the temporal fascia is exposed and incised A bone-elevator is now inserted beneath the fascia the instrument comes to lie upon the musculus temporalis which inserts at the processus coronoideus If the instrument is pushed downward between fascia and muscle it inevitably finds its place mediad to the depressed fragments of the zygomatic arch A gauze pad is laid upon the scalp posterior to the instrument to act

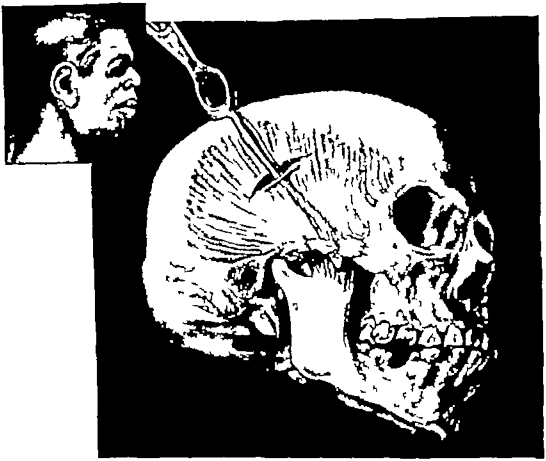

Fig. 261 Depressed fracture of zygomatic arch (reduction after Gillies) From incision within hairline of temporal region, temporal fascia is exposed and incised. Above elevator is passed between fascia and musculus temporalis until it finds its place median to depressed fragments. Pressure upon handle of instrument elevates tip of instrument and thus the fragments.

as a fulcrum and protector for the temporal bone. Downward pressure is now exercised upon the instrument thus elevating the fragments The reduced fragments usually remain in position without support for there are no strong muscles attached to them The wound is closed in layers

If the fragments do not remain in place (this is usually the case in badly comminuted fractures involving the entire malar bone or it may happen in cases of complete separation of the malar bone from its at tachments with or without fractures of the orbital floor) fixation can be

in alignment In comminuted fractures with a tendency to spread, the fragments are kept in alignment with a mattress suture of thin wire, which is passed through skin, nasal bones, and mucosal septum on one side, then passed through the other side and back The suture should be passed through lead plates on both sides

Correction of septal deformities should follow the reduction of the bony fragments.

For treatment of old, unreduced nasal fractures, see p 334.

Deformities and Improper Function

MANDIBULAR PROGNATHISM

Mandibular prognathism is a protrusion of the mandible, often associated with underdevelopment of the maxilla If extensive, the protrusion not only produces a deformity, but also causes malocclusion of the teeth The incisor teeth of the mandible are from 1 to 2 cm ($\frac{3}{8}$ to $1\frac{3}{16}$ inch) in advance of the upper teeth This, in turn, causes functional disturbances, such as disturbances of mastication and phonation The conditions may be congenital or due to developmental errors, such as faulty eruption of the teeth, or due to endocrine disturbances (acromegaly) It is seldom the cause of trauma or infection Before the ages of twelve to fourteen years, moderate degrees of prognathism can be corrected by orthodontic treatment Later on, and in severe cases, only surgery can correct it

Many methods have been devised to overcome the deformity and to obtain occlusion of the teeth The various operations can be divided into two groups, ostectomy and osteotomy Although no single method is applicable in all cases, the preference of the surgeon for one technic may outweigh any slight advantage of alternate methods if satisfactory occlusal relationship can be achieved A large list of references concerning this subject is published by Sarnat and Robinson *Ostectomy* is performed from the body or angle or condyles of the mandible (Blair, Pickerill, Harsha, Dufourmentel, Schultz, Kazanjian, Henschen and Schwartz, New and Erich, Kitlowski, Gonzales-Ulloa, Smith, and others) *Osteotomy* is performed through the ascending ramus between the foramen and incisura mandibulae (Babcock, Pichler, Lindemann-Bruhn, Kostecka, Ivy, Scher, Newman, Henry, and others)

The correction of various jaw deformities including prognathism has been well covered by Waldron, Kazanjian, Converse, and Shapiro The author prefers bilateral osteotomy through the ascending ramus in cases of moderate protrusion and malocclusion, if accompanied by severe malocclusion, osteotomy of the body of the mandible is performed This latter procedure is also apt to narrow the mandibular arch, which in

A force striking laterally separates the nasal bones from the frontal process of the maxilla or breaks the latter off and severs the frontonasal sutures. The nasal pyramid is displaced in the line of force the septum becomes deviated in extreme displacements it may even become dislocated from its insertion in the vomerine groove.

If the striking force has an anterior direction the nasal bones become displaced posteriorly and between the frontal process of the maxilla or they may become displaced laterally causing the flat, broad nose. In either case, the nasal bones become separated from their anterior and frontal attachments the septum may break or become dislocated and deviated causing marked obstructions and additional deformities.

The majority of nasal fractures are compound and comminuted, causing hemorrhage and marked swelling of the surrounding soft tissues The swelling may be so marked as to make a correct clinical diagnosis impossible. Intranasal examination for disclosure of any deviation of the septum may be of value. X ray pictures may reveal the line of fracture but—as a rule—are of little value concerning the relationship of the fragments.

Treatment Fractured nasal bones without displacement do not need any other treatment except for that applied in injuries of soft tissues Fractures with resulting displacement however should be reduced as soon as possible. The reduction is performed under local (cocainization) (see p 318) or general anesthesia (intravenous injection of sodium pentothal)

Lateral Displacement Reduction is accomplished either manually by pressure of gauze-padded thumbs on the deviated side or with a well padded Kelly forceps The latter grasps the side which is nearest the mid line (concave side) Since the fragments are not only displaced laterally but resting posteriorly and beneath the maxilla, the direction of the reduction must be anteriorly and outward (Fomon) After reduction of the fragments, the nasal septum should be inspected If it is still dislocated it should be forced into proper position with a forceps if this fails the dislocated edge should be lifted with an elevator and forced into the vomerine groove (p 335) Immobilization is achieved by packing the nose with iodoform gauze which should be removed after forty-eight hours. A medium-sized cork is halved longitudinally and placed with its flat side upon the deflected side and held with adhesive strips (see p 338) Another way of immobilization is that of Blair described on p 338

Horizontal Displacement In fractures due to forces striking from an anterior direction the flattened nasal pyramid must be elevated A bone-elevator or any other suitable instrument inserted beneath the fractured nasal bones lifts the latter while thumb pressure molds the pyramid from the outside A bilateral-cork application (p 323) may hold the fragments

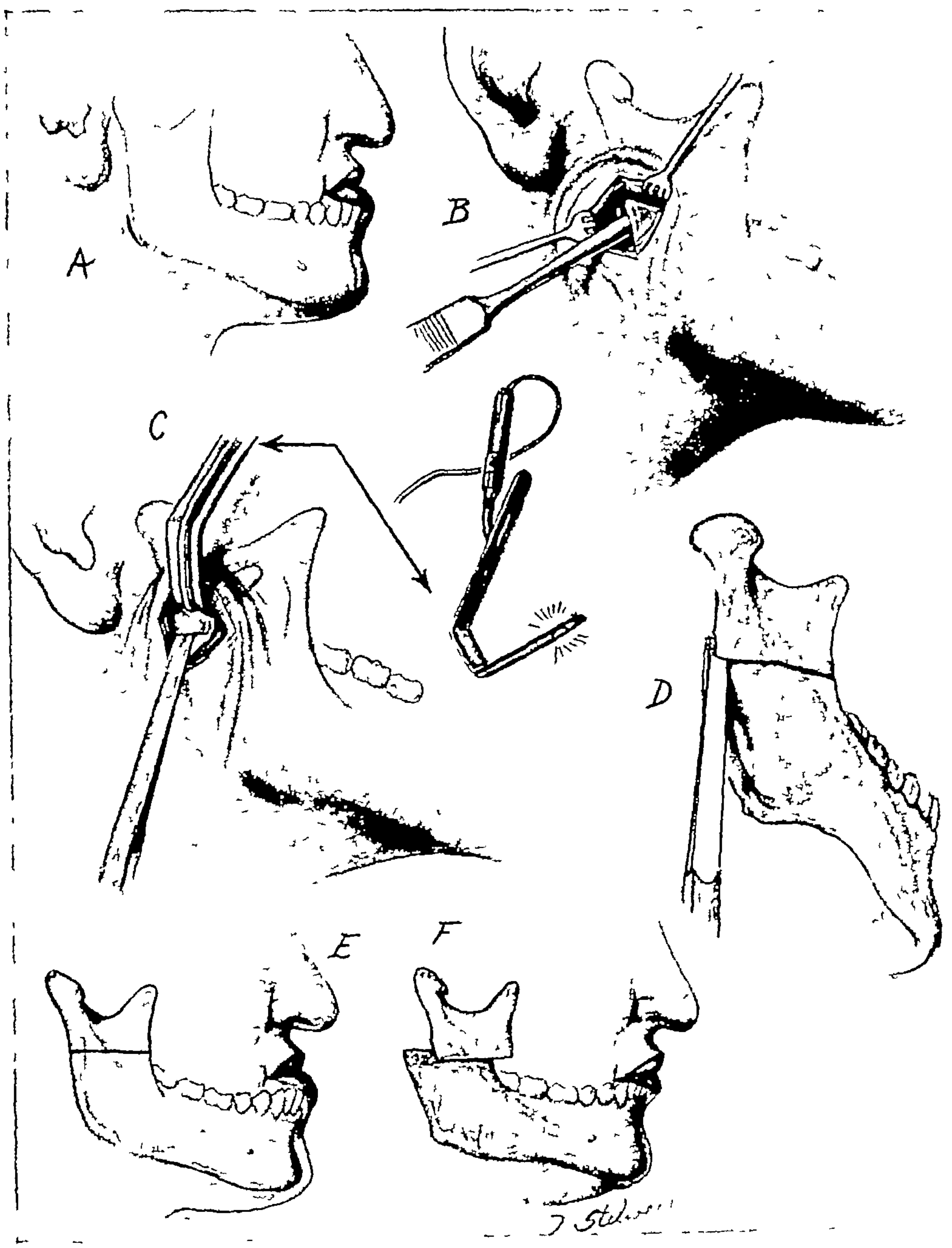

Fig 263 Technic of osteotomy of the ramus for correction of mandibular prognathism A Small external incision made above the angle of the jaw B· The periosteum and masseter muscle are raised from the outer aspect of the ramus C Subperiosteal retraction, with an illuminated retractor, gives exposure for osteotomy D The osteotome, introduced from below, cuts through the ramus obliquely D, F Backward displacement of the mandible after osteotomy (Converse, J M Plast. & Reconstruct. Surg)

more severe cases as a rule is larger than the alveolar arch of the maxilla. Babcock was the first to devise osteotomy through the ascending ramus he used an osteotome Kostecka modified the method by using the Gigli saw The section is performed through the inferior alveolar foramen thus preserving joint function and the integrity of the nervus alveolaris inferior The thinness of the bone at this level may cause loss of contact of the fragments and nonunion particularly after use of a Gigli saw The author has not encountered this but became aware of the possibility after a postoperative displacement of the fragment due to vomiting To counteract this the operation should be performed under local

Fig. 262: Blair's full-curved suture-carrier needle.

or sodium pentothal anesthesia Others (Kazanjian Pomroy and Cabrol Converse) have advised an oblique osteotomy of the ascending ramus establishing an outward and upward level in the lower fragment and thus counteracting the pull of the external pterygoid muscle and preventing median rotation of the condyle and loss of bony contact.

The surgical treatment of prognathism can be divided into three stages preoperative measures the operation and after treatment. For the preoperative preparation and after treatment the congenial collaboration of a competent dental colleague is indispensable

Preoperative Measures These procedures consist in making casts of the denture providing x ray pictures and splinting With the casts on hand the degree of protrusion is determined. The x ray pictures are of value to define the position of the foramen mandibulare Preoperative splinting in preparation of adequate postoperative immobilization can be performed in various ways. The most satisfactory retention splint is the half round arch wire splint to upper and lower teeth as described on p 417

Technic (Transverse Section of Ascending Ramus after Kostecka) (Case 73 p 912) Before the operation the previously attached arch wires of the jaws are connected to each other by elastic bands thus counteracting sudden gross displacement of the mandible after the second side of the mandible is severed A stab wound is made through the skin

at the posterior border of the mandible, about 2 cm. (13/16 inch) below an imaginary horizontal line passing through the center of the meatus acusticus externus. Blair's full-curved special needle (Fig. 262) is introduced into the wound and passed around the posterior border of the mandible. It is then pushed forward between the median surface of the ramus and the musculus pterygoideus internus, in close contact with the bone, and emerges through a stab wound through the skin of the cheek at the anterior border of the ramus. In this way, neither the nervus facialis, the nervus alveolaris inferior, nor larger vessels are in danger of being injured, the oral cavity is not penetrated. The eye of the needle is armed with a strong silk thread, which is attached to a Gigli saw. Needle, thread, and Gigli saw are now withdrawn through the first incision. *With the Gigli saw in place, the ramus is severed between* foramen mandibulare and incisura mandibulae (compare with Fig. 240). The same procedure is carried out on the other side. Bleeding is arrested by pressure.

The body of the mandible is now pushed back until satisfactory occlusion of the teeth is obtained. The previously attached arch wires of upper and lower teeth are connected with brass tie wires (compare with Fig. 245).

After-Treatment: Postoperative care does not differ from that of mandibular fractures (see p. 419). Position of fragments should be checked by x-ray examination. The connecting wires should be tightened weekly. Immobilization is required for from eight to ten weeks.

Technic (Oblique Section of Ramus after Ponroy-Cabrol, Kazanjian-Converse) (Fig. 263). A vertical incision about 1.5 cm. (5/8 inch) in length is made through the skin along the posterior border of the ramus, just above the angle where the ramus is felt immediately beneath the skin, thus avoiding the parotid gland and facial nerve. Following the incision, the subcutaneous tissues are separated by blunt dissection, and the periosteum is exposed and incised widely, the insertions of the masseter muscle are then elevated subperiosteally. The soft tissues are raised and the lateral surface of the ramus exposed by means of an elongated retractor. With a narrow osteotome under direct vision, the ramus is cut on the bevel obliquely from below upward, the line of section is established above the inferior alveolar foramen. It lies about 2 cm. (3/4 inch) below an imaginary horizontal line passing through the center of the meatus acusticus externus. The level of the inferior alveolar foramen may be located on the outside of the face previous to the osteotomy (the lateral x-ray film of the skull should be referred to). For the steps following repositioning and the after-treatment, see previous technic.

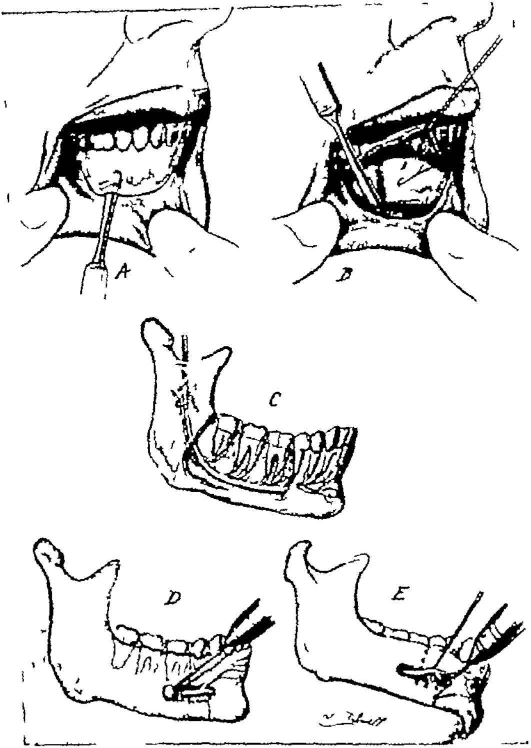

Fig. 264 Technic of intra-oral step-osteotomy of the body of the mandible for correction of mandibular prognathism. *A.* Wide flap to expose the lateral aspect of the body of the mandible. The *periosteum is being raised. B. The outer aspect of the body of the mandible is exposed* the branches of the mental nerve are preserved. *C:* Drawing, representing the inferior alveolar nerve trunk, showing the mental nerve and the anterior inferior alveolar branch (shaded). *D* The inferior alveolar canal is uncovered by removing the outer plate, thus exposing the neurovascular *bundle. E. Step-osteotomy is* performed without sectioning the inferior alveolar neurovascular bundle. (Converse J. M.: Plast. & Reconstruct. Surg.)

retromolar region The mucosa is dissected away from the underlying muscle until the lower border of the mandible is exposed The periosteum is then incised along the lower border and a mucoperiosteal flap is raised to expose the lateral surface of the mandible, the foramen mentale being located and exposed This indicates the level of the inferior alveolar canal, which can be exposed by removing the outer table of bone with a large, round dental burr Thus, the inferior alveolar bundle comes into view and can remain under direct vision and be safeguarded during the following procedure (should the nerve be accidentally severed, regeneration occurs after varying periods of time) A step osteotomy is now performed through the mandible, with removal of an upper and a lower segment of bone (Fig 265) The segments are marked out on the cortex of the mandible by a groove made with the electrically driven burr With the same burr, the mandible is perforated along the steplike line of osteotomy (Fig 264, *E*), at first vertically from the posterior border of the socket of the extracted tooth to a point some distance below the mental foramen (to avoid damaging the roots of the teeth), then forward in the horizontal plane to the anterior border of the lower bone segment, which is to be removed later on From here, a vertical line of perforation is extended downward to the lower border of the mandible The upper and the lower bone segments are now outlined with perforations (Fig 265, *A*) The bone between the holes is cut through with a fissure burr, and the fracture and excision of the two bone segments are completed with a narrow osteotome The separated rami are approximated and fixed by wiring the bone ends together and by interdental-wiring appliances made and secured to the teeth before the operation (Compare with Fig 266) (These consist of a mandibular splint of half-round arch wire constructed in three parts [see also p 417] and a half-round arch wire to the upper teeth) Crushing or pinching of the nervus alveolaris is avoided by wide decompression of the canal The two mucoperiosteal flaps are reflected back and sutured A figure-of-8 Barton bandage (Fig 241) is applied for pressure to prevent hematoma and to aid in fixation

Dingman (unpublished) uses the staircase type of section only in cases where the posterior fragment is edentulous, in other cases he uses a straight section through the mandible He also operates from an inside incision for severance of the upper half and from an outside incision (well below the mandibular branch of the facial nerve) for section of the lower half of the bone The fragments are held together with a wire suture.

Technic (Intraoral Step Osteotomy of Body of Mandible after Kazanjian-Converse) (Figs 264 266) The indication for this operation has been discussed on p 438 antibiotics are routinely employed pre and postoperatively It is usually necessary to extract a bicuspid tooth on each side A large horseshoe shaped incision is made through the mucosa of the cheek just lateral to the gingival sulcus from the mental to the

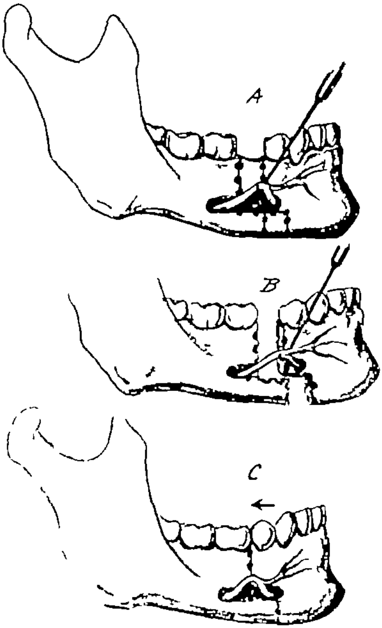

Fig. 265: Contd. Step-osteotomy with resection of a bone segment to shorten the body of the mandible. *A:* The inferior alveolar canal and neurovascular bundle are exposed. *B:* A segment of bone determined pre-operatively is removed. C The anterior segment is moved posteriorly achieving contact of the fragments. Pinching of the inferior alveolar nerve is avoided. (Converse J M. Plast. & Reconstruct. Surg.)

dyles (Babcock); and intraoral insertion of prosthetic appliances into an epithelium-lined pocket between lip and mandible (Gillies)

Technic (Retrusion Unassociated with Malocclusion): In moderate retrusion, Converse's intraoral technic of inserting an iliac bone graft is used, thus obviating an external scar, otherwise, the external approach is advisable

Intraoral Approach (Fig 267, Case 74, p 943) In using this approach, certain precautions must be taken A bone graft is used to build up the chin, the bone graft is taken before the intraoral exposure of the

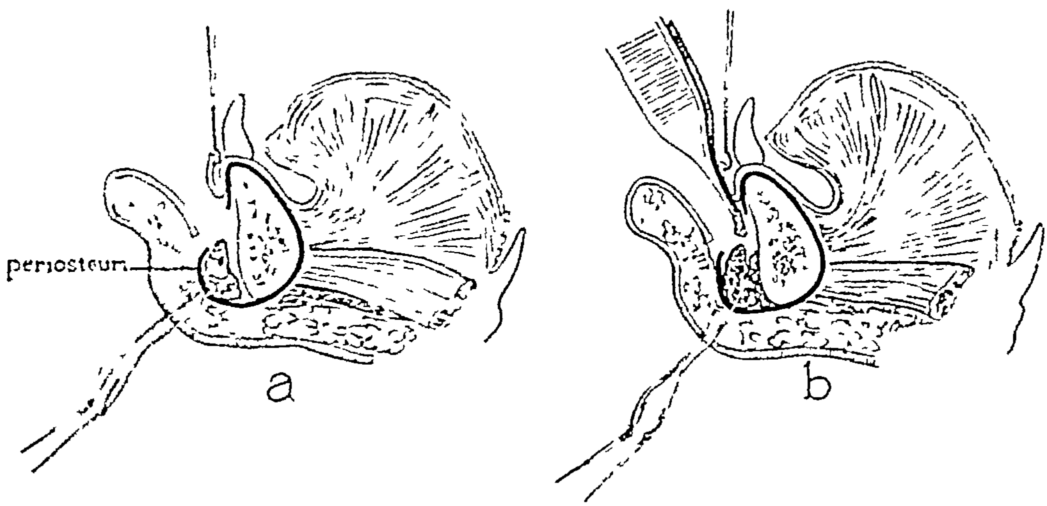

Fig 267 Intraoral approach for bonegrafting in correction of mandibular retrusion Use of traction sutures for the placing of bone grafts in the region of the symphysis via the intra-oral approach *A* The bone graft is held in correct position by guide-traction sutures placed through the soft tissues of the chin *B* Bone chips are packed between the host bone and the bone graft in order to provide sufficient projection of the graft (Converse, J M Plast. & Reconstruct Surg)

mandible; it is placed subperiosteally, which causes an advancement of the lower lip and the musculature. This places tension upon the mucosa of the lower lip, and may result in gaping of the mucosal wound edges Hence, the incision must be placed high above the cul-de-sac of the sulcus to permit easy closure A thick mucosal flap is dissected to the periosteum, the latter is incised and raised with a sharp periosteal elevator, exposing the mandible. Elevation of the periosteum is extended downward to the lower border of the symphysis, and may be extended laterally to the mental foramen or even beyond An incision about 2 cm (3/4 inch) in length, usually placed to the side of the frenulum, gives adequate exposure for small implants For wider exposure when larger grafts are used, an incision about 5 cm. (2 inches) in length is required, extending across the inner surface of the lower lip Even in the wider exposures, the mental nerve and vessels remain attached to the soft tissue,

RETRUSION OF MANDIBLE

Shortening of the mandible may occur on one or both sides it is rarely congenital in the majority of cases it is due to trauma or disease or to faulty eruption of the teeth In some cases especially in ankylosis of the jaw from accidents during childhood, it is due to failure of development because of lack of muscle function (Thoma) The retrusion may or may not be associated with malocclusion of the teeth In the former

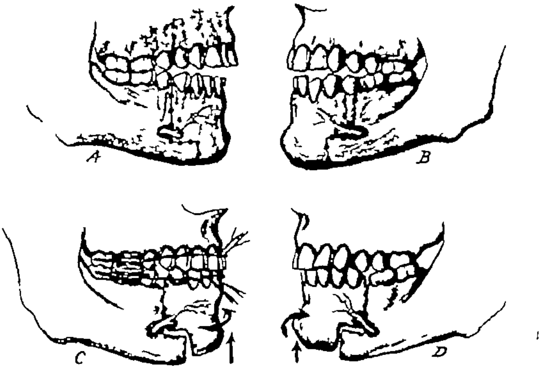

Fig. 266 Technic for surgical correction of open-bite A. Step-osteotomy following exposure of the inferior alveolar nerve on the right side. B: On the left side, removal of a tooth permits the resection of a V-shaped segment of bone. Step-osteotomy follows. C D The anterior segment of the body is displaced upward and rotated forward and toward the left side. (Converse J M: Plast. & Reconstruct. Surg.)

case it causes a deformity plus functional disturbances, such as disturbance of mastication and phonation In the absence of malocclusion retrusion constitutes a deformity only In retrusion unassociated with malocclusion the deformity is corrected by building up the chin contours with grafts, such as fat (Lexer Newman) bone or cartilage (New Erich)

The various methods for correction of retrusion associated with malocclusion can be divided into osteotomies through the ramus (Blair and Ivy Padgett Scher and others) through the body (Bruhn Kazanjian and others) through the body associated with transplantation of bone grafts (Limberg) insertion of cartilage implants behind the head of the con-

long The step of the osteotomy line also needs reversal, namely, posteriorly instead of anteriorly to assure a longer horizontal fracture line and fragments The alveolar nerve should be safeguarded The line of the osteotomy then runs as follows With a dental burr, the mandible is cut from the alveolar ridge downward in front of the mental foramen,

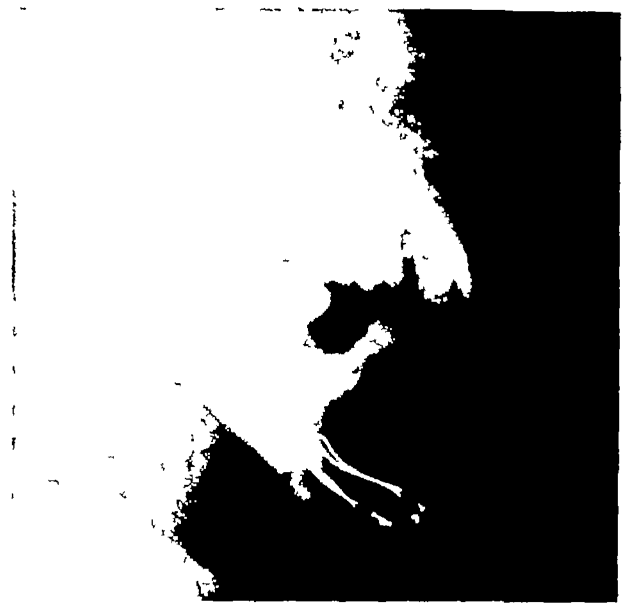

Fig 268 Marked underdevelopment and retrusion of mandible Onlay bone graft from crest of ilium fastened to anterior part of mandible (compare with Case 76, p 945)

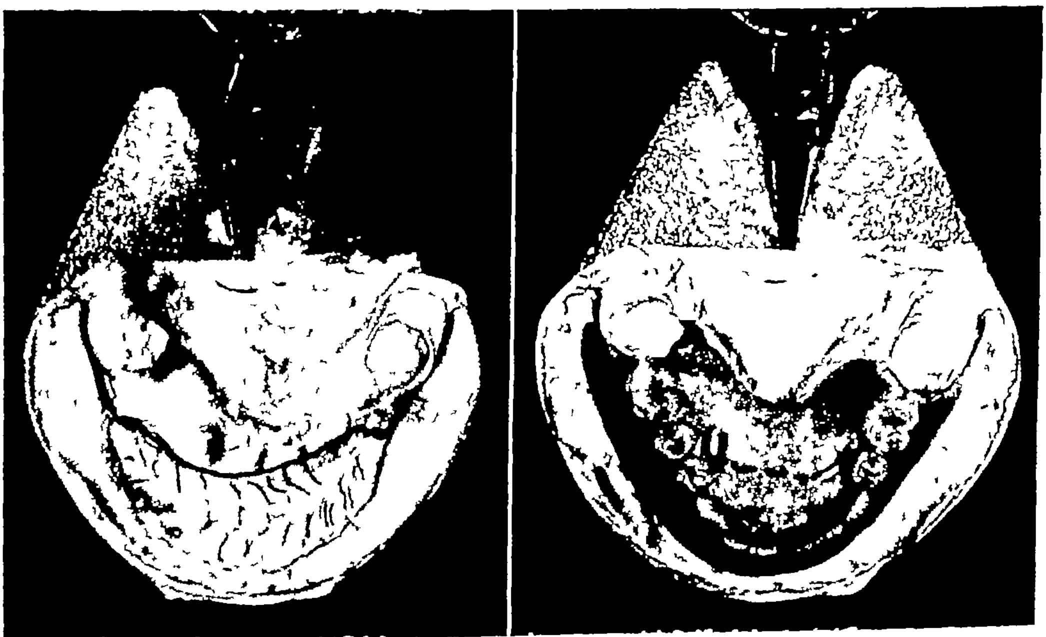

Fig 269 Moulages before and after skin inlay grafting of case of Fig 268 (compare with Case 76, p 945) *A* Heavy line indicates original sulcus, broken line and shaded area marks out skin-lined pocket in front of mandible. *B* Prosthesis inserted into pocket, broken line indicates original alveolar ridge

thus permitting bone-grafting either anterior or posterior to the foramen. An iliac bone graft (from median plate of ilium) (for removal of graft see p 64) comprising of cortical and cancellous portions is removed and suitably shaped by trimming the cancellous part and placing the cortical portion against the mandible The cortical part may be bent to yield to the contours of the mandible. Numerous chips of cancellous bone are used to supplement the main bone graft. These chips are placed between the bone graft and the mandible to support the graft and to provide projection to the implant. Such chips are also packed in the interstices between the bone graft and the host bone to eliminate dead space Flat pieces of bone are used to shape the contour of the lateral areas of the body of the mandible Traction-guide sutures are useful when placing chin implants (Fig 267) These are removed at the end of the operation The implants are further maintained in correct position by strips of elastoplast on the skin over the grafts The first strip is placed in the labiomental groove to maintain the graft over the symphysis Successive strips of elastoplast are then placed over the chin These are anchored by strips of adhesive to maintain firm immobilization for from five to seven days

Extraoral Approach (Cases 75 76 pp 944 945) An incision is made below the chin through skin subcutaneous tissue and muscles Either two superimposed cartilage grafts (for removal see p 58) or an iliac bone graft (from crest of ilium) is used (for removal see p 63) the latter consists of cortical and cancellous portions It is suitably shaped by trimming the cancellous part The cortical part comes to lie against the body of the mandible A pocket is prepared in front of the mandible by stripping soft tissues and periosteum from the bone. The graft is fastened to the bone by drilling holes through graft and bone in such a way as to allow the passage of two mattress sutures of stainless steel (Fig 269) The wound is closed in layers and a moderate pressure dressing is applied

Technic (Retrusion Associated with Malocclusion) If the retrusion of the mandible is associated with ankylosis of the temporomandibular joints arthroplasty should be performed first (Kazanjian) (see p 450) In bilateral ankylosis a two-stage procedure is preferable It is also important to make provision for immobilization of the mandible following operation (see p 439) For correction of the retrusion the author prefers the osteotomy through the ramus and sliding the mandible forward (pp 439 442) (Lindemann Axhausen Wassmund Schuchard) The steplike osteotomy through the body of the mandible as described on p 443 is also available (compare with Fig 266) To permit good coaptation of the bone the horizontal fracture line must be made sufficiently

Technic (Blair): The principle is bilateral excision of a V-shaped section of the mandible just in front of the first occluding tooth. The apex of the V-shaped section is at the lower border of the jaw, and usually a tooth must be extracted from the site of the section on each side; the tooth extraction should be performed several months prior to the operation. Plaster reproduction of the denture will reveal the size of the piece of bone to be resected. An incision is made below the mandible at the selected site, the mandible is exposed, and the V-shaped piece of bone—together with its periosteum—is resected with a straight or electrically driven saw from below upward into the mouth. The same procedure is undertaken on the other side. A drain is now inserted externally, and the wounds are closed. The anterior fragment is now brought into occlusion with the upper teeth and immobilized by interdental splinting.

If the open bite is associated with retrusion or protrusion of the mandible, the technics described in the former paragraphs (p. 447) (compare with Figs. 264–266) should be considered.

BONY ANKYLOSIS OF TEMPOROMANDIBULAR JOINT

This condition may be unilateral or bilateral. It may be congenital or acquired. If acquired, it is due either to trauma or to infection. To overcome the ankylosis, arthroplasty is necessary, and requires the removal of a section of bone, followed by interposition of local tissue or tissue grafts to prevent reunion. The bone is removed either from the base of the condyle (Helferich, Murphy, Blair) or from the ramus. The author prefers the resection of a piece of the ramus, and follows Risdon's technic.

Technic (Risdon): An incision is made, starting behind the angle of the mandible and running forward about 4 cm. (1⅝ inches). Enough skin and subcutaneous tissue is reflected upward to obtain access to the inferior attachment of the musculus masseter. The latter is stripped from the mandible almost to the bony deformity that caused the ankylosis. Then under direct vision, the ascending ramus is divided transversely with a Gigli saw (see p. 439) or with dental burrs of various sizes beneath the sigmoid notch. The cut is enlarged by using a large fissure burr. When the inner plate of the bone is reached, great care must be taken in dividing it, since the arteria maxillaris interna may lie close to the ramus. It may be necessary to cut the inner plate with a chisel. After the division of the ramus, a piece of bone, about ½ cm. (¼ inch) wide, is removed from the anterior fragment with a rongeur. A piece of the detached masseter muscle is now placed into the gap and sutured to the musculus pterygoideus internus to counteract reunion of the fragments. If the gap cannot be filled with the masseter muscle, Kazanjian covers the an-

then backward below the alveolar canal and then downward again across the posterior border of the mandible. The extended fragments are held together by a bone suture of wire and by interdental wiring If teeth are absent, a circumferential wire is passed around the symphysis and brought out through the skin of the chin and twisted to form a loop The loop is then attached to a special headgear under traction as described by Kazanjian. In unilateral retrusion only the short side is elongated unless occlusion of the teeth remains unsatisfactory whereupon the other side must also be severed

Technic (for Severe Retrusion) (Case 76 p 945) In severe retrusion particularly in which the lip is pulled back by its attachment to the gums osteotomy is either insufficient or not possible at all owing to thinness of the mandibular bone The method of choice in these cases is the intra oral insertion of a prosthetic appliance into an epithelium lined pocket between lips and mandible (after Gillies) If the mandible is sufficiently thick, a step osteotomy is performed first otherwise (as in Case 76 p 945) a platform must be built first in front of the mandible with an iliac bone graft on which the intraoral prosthesis will later rest (Fig 268) After the bone graft has healed in place the intraoral epithelium lined pocket is made Between lip and mandible a cavity is prepared and lined by insertion of a skin graft wrapped around a stent, as described on p 37 The pocket should extend down to the lower border of the mandible and should be made large enough to improve or possibly correct the deformity After six days the stent of dental compound is removed and replaced by a prosthetic appliance which carries artificial teeth The latter are attached to the prosthesis in such a way that they are in occlusion with the teeth of the maxilla and hide the teeth of the retruded mandible For a few days after the appliance is inserted the lower lip which is stretched and tense has a tendency to contract downward To counteract this retraction New and Erich advise the use of adhesive tape to hold the lower lip in the desired position until the contracture is overcome.

OPEN BITE

Open bite is a condition in which after closure of the jaws the frontal teeth cannot be brought into occlusion In rarer instances the condition is due to a malunited fracture The most common cause is a developmental fault whereby the anterior part of the mandible is bent downward in front of the second molar In some cases the maxilla is the seat of the deformity Before the age of twelve, the condition may be corrected by orthodontic treatment in older cases however surgery may become necessary if the functional disturbance demands correction

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terior fragment with fascia lata others (Braithwaite and Hopper and others) insert a piece of cartilage between the fragments Then follows closure of the wound

Motion can be started as soon as possible The use of a trismus appliance (Ivy) or exerciser (Kazanjian) may be of great help in establishing function

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definitely less after skin-grafting It should be pointed out that the graft on the anterior surface of the neck must be laid horizontally and not vertically so that, for the reasons mentioned in the preceding paragraph, the scars between the grafts come to lie within the creases of the neck.

Tracheal Fistulas: Tracheal fistulas are of several kinds, and the technic of their closure varies accordingly. The fistula that remains after simple tracheotomy for acute laryngeal obstruction, necessitating the wearing of a cannula for only a few days or weeks, presents no problem, for it closes spontaneously and almost immediately. On the other hand, if the cannula has been worn for a number of months or years, it will not, as a rule, close tightly without a plastic procedure. In such cases, after at least a week or two has been allowed for partial spontaneous closure, the epithelized fistulous tract is dissected down to the tracheal wall, ligated, and amputated, after which the subcutaneous tissues and the skin are closed without drainage. Larger openings, such as those used for the insertion of laryngotracheostomic apparatus in the treatment of severe chronic laryngeal stenosis, must be closed with special precautions to avoid narrowing the airway, and, of course, closure must not be attempted at all until suitable tests have been carried out to prove that sufficient permanent dilatation has been accomplished. Such openings must be closed by simply covering them, as with a lid, care being exercised to avoid sutures that tend to pull the lateral margins of the opening together. This can be accomplished, in most cases, by making an elliptical incision about the opening and then inverting the inner skin edges in such a way as to roof over the opening with skin The outer skin edges are then undermined and united in the midline.

In the case of some larger openings, it is safer to make the closure in stages, closing the part of the opening over the narrowest point in the airway first, so that if there should be temporary narrowing from postoperative inflammatory reaction, the patient can still breathe through the part remaining open In a second stage, this remaining opening can be closed with no fear of obstruction in the postoperative period. Occasionally, a more elaborate type of plastic procedure may be deemed preferable, using a pedicle flap (Erdelyi), with or without a cartilage implant and lining

Deformities

CONGENITAL BANDS (PTERYGIUM COLLI)

Designated "pterygium colli" by Finkle in 1902, these bands stretch from the mastoid region to the acromion They may be unilateral or bilateral, and may or may not be associated with other congenital condi-

XIII

THE NECK AND LARYNX AND TRACHEA

Defects

WOUNDS burns and tracheal fistulas are the principal defects of the neck that require reparative and reconstructive procedures

Wounds Treatment does not differ from that already outlined in Chapter III A few special points however should be emphasized The normal creases of the skin of the neck run horizontally Hence, vertical wounds crossing the normal creases heal with less cosmetic and functional satisfaction than horizontal wounds They are apt to contract and to form a web which may require later repair by a Z-operation For the same reason wounds which need lengthening should be extended horizontally and not vertically The same principle holds good for all operative incisions around the neck Deep wounds at the anterior surface of the neck, often the result of suicidal attempt are complicated by injuries to the larynx trachea muscles, and—surprisingly less often—to major vessels and nerves. Each structure requires special attention If larynx or trachea is injured tracheotomy must be performed below the injury before the perforation is closed.

Burns Here again the therapeutic principles are the same as those for burns in other regions (Chap IV) In third-degree burns skin-grafting should be performed as soon as possible to prevent contractures which inevitably lead to poor functional and cosmetic results Difficult to deal with are those deep burns in which the platysma is destroyed. Even if early skin-grafting has been performed a contracture and an obliteration of the chin neckline may result The degree of contracture, however is

and extent of the cicatricial changes In mild cases—that is, the scar being soft and weblike—the deformity can be corrected by one or several Z-operations (p 147) The triangular flaps for the formation of the Z should include skin only, while the underlying platysma should be excised and removed. In cases with numerous webs, the Z-operation is not likely to be successful In one of the author's cases, the immediate cosmetic effect was good, but the webs recurred In such cases, there appears to be too much skin, while the actual seat of the contracture is the platysma

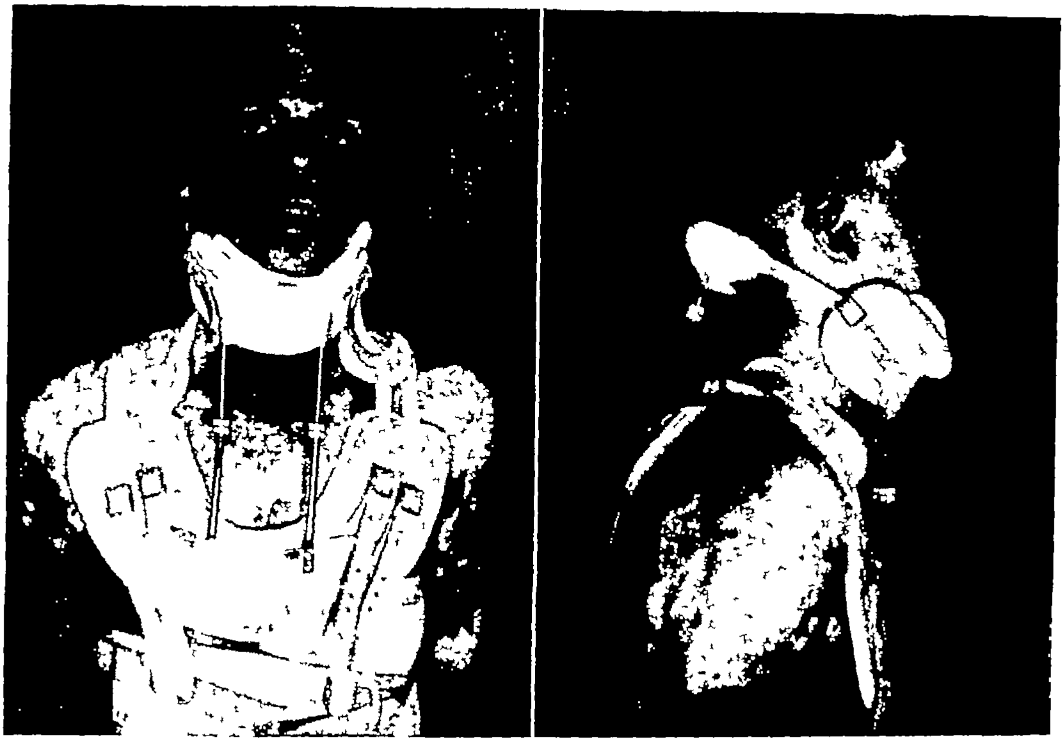

Fig 270 *a-b* Adjustable brace (after Cronin) individually made to splint the neck after repair of cicatricial contractures of the neck with skin grafts

In the aforementioned case, the author improved the condition by making a T-incision (the horizontal part in the chin-neckline, the vertical part over the trachea) and dissecting two triangular skin flaps They were reflected laterally. This opened the entire anterior surface of the neck The platysma was excised, and the skin flaps were reflected back in place and trimmed to conform to the new contours

In very extensive cases with ectropion of the lower lip, relaxation incisions to overcome the contracture are not sufficient The entire scar must be excised until normal tissue is reached Only then is one able to release the contracture. The raw surface is covered with a thick split graft A full-thickness graft is contraindicated for reasons mentioned on p 25 (Case 77, p 946) For the reasons given on p 455, the grafts on the an-

tions such as concomitant axillary webs or malformations of the cervical spine (Klippel Feil syndrome) Bettman described these bands pictur esquely as though a rope had been spanned across and the skin then draped over it and allowed to hang in a graceful festoon Between the leaves of pterygium colli one finds connective tissue and even muscle tissue. The latter however has no connection with the skeletal muscles outside the pterygium

To correct such a web one may be tempted to give Z plasty a chance but unless multiple Z s are used the operation will not be successful since the hairline becomes displaced to the anterior surface of the neck and relaxation may not be sufficient. The author has followed Bettman s advice with gratifying results

Technic The crest of the web is brought into prominence by push ing the head toward the other shoulder An incision is now made along and through the entire crest down to the skeletal muscles. Two incisions about 3 8 to 5 cm (1½ to 2 inches) long, are made at right angles to the first (longitudinal) incision at different levels—the upper one on the posterior side about one-third the length of the primary incision the lower one on the anterior side about two-thirds the length of the primary incision All incisions go through the subcutaneous layer and connective tissue bands to the muscular layers The flaps are widely undermined. Care must be taken not to injure the nervus accessorius which lies on the splenius muscle. The point of one flap of skin will automatically fall into the angle of the opposite incision, and vice versa Additionally one or more similar but shorter right-angle incisions are made above or below or both followed by interchanging flaps and closure of the wounds If both sides are affected they are operated upon in the same stage. A voluminous pressure dressing is then applied If the Klippel Feil syn drome is associated with deformities of the shoulder girdle additional bone operations may become necessary (Bonola)

CICATRICIAL CONTRACTURES

Cicatricial contractures of the neck constitute the majority of deformi ties. The scars causing the contractures are as a rule due to burns and run longitudinally on the anterior and lateral surfaces of the neck. They obliterate the chin neckline, causing an awkward straight profile. In extensive cases involving the deeper tissues, chin and lip are pulled on the chest, causing ectropion of the lip and marked limitation of motion.

Technic: The patient is operated upon in the dorsal position with the shoulder elevated on a pillow to cause a backward tilt of the head and stretching of the neck. The correction depends entirely upon the depth

terior side of the neck must be laid horizontally and not vertically thus the adjoining scars come to lie within the creases of the neck To avoid lateral contracting webs it is also important to break up the lateral vertical borders of the graft with a Z plasty Only rarely will it be found necessary to use a flap which owing to length must be delayed The flap tubed or untubed is prepared from the back, chest or thoracoepigastric region They as a rule must be transferred in stages

After Treatment A heavily padded pressure dressing is applied, and the patient is placed in bed with the head tilted backward. The dressing is changed on the eighth day the sutures are removed

Proper splinting holds the clue to the success of the skin-grafting and here Cronin has provided a most helpful suggestion As is frequently the case recurrence of some of the contracture with wrinkling of the graft, is almost certain unless the neck is splinted properly and continuously for about six months Cronin advises construction of a well fitting brace one week after the operation He demonstrates several types of which the safest is the adjustable splint (Fig 270) (compare with Case 77 p 946) The brace is formed from a plaster-cast mold and consists of a piece of metal shaped to the general contour of the neck It is lined with a thin layer of foam rubber and covered by soft calfskin As the lining is applied to the splint great care must be taken to avoid loss of the desired contour

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DIVISION THREE

THE TRUNK

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XIV

INTRODUCTORY ASPECTS OF THE TRUNK

THE general principles of repair and reconstruction are those which have been discussed in detail in the first part of the book, and will not be stressed.

The problems selected are of special nature and those in which the general surgeon as well as the general plastic surgeon are interested. The subject is divided into anatomical regions and discussed in the following five chapters.

Anesthesia

The agents and methods used in operations on the trunk are ether, alone or in combination with the gases, such as nitrous oxide ethylene cyclopropane or in combination with solution of tribromoethanol (avertin) local anesthesia is provided with procaine either alone or in combination with sodium pentothal or solution of tribromoethanol (avertin) for spinal anesthesia procaine, metycaine tetracaine (pontocaine) in operations below the diaphragm For long operations under spinal anesthesia the method of choice is continuous spinal anesthesia for short anesthesia sodium pentothal alone or in combination with nitrous oxide. Endotracheal methods of anesthesia are not necessary in this section of the body unless absolutely indicated.

For details concerning the various agents and methods mentioned here the reader should refer to standard textbooks on anesthesiology

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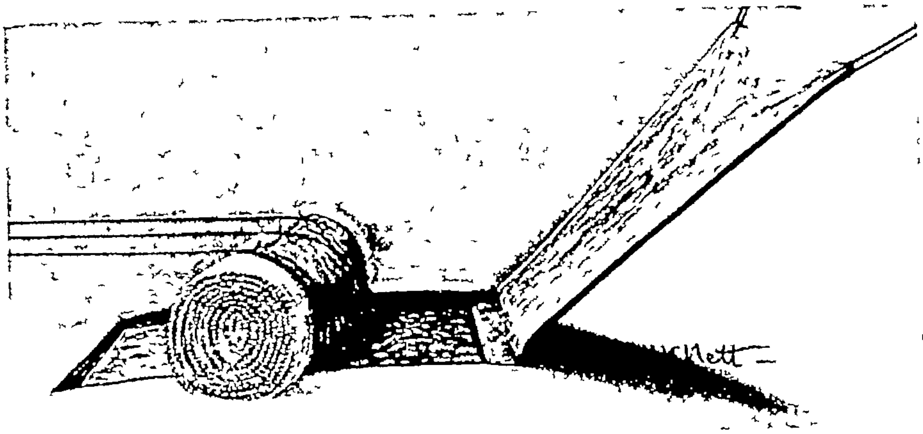

Fig 271 Removal of dermal graft to be used in hernial repair Epidermis to be used later to cover donor area Derma being removed by excision

Fig 272 Recurrent inguinal hernia. Incomplete closure, tension on sutures of conjoined tendon and Poupart's ligament.

XV

THE ABDOMINAL WALL AND THE BACK

Defects

OF THE defects of the abdominal wall the incisional hernia requiring tissue grafts for closure has been selected as a typical example. The same technic is applicable for other large defects, such as inguinal hernias with defective structures or defects resulting from removal of tumors.

INCISIONAL HERNIA REQUIRING TISSUE GRAFTS FOR CLOSURE

Indication for the use of a strong tissue graft in repairing an incisional hernia arises in cases where the hernial defect is so large that overlapping the aponeurosis of the defect's edges is impossible The graft most suitable for this purpose is the derma that is the epithelial denuded skin (see p 42) It is stronger than fascia or any other connective tissue and owing to metaplasia assumes the characteristics of the tissue surrounding it (Rehn) a further advantage is that it is readily available G B Mair employed whole-thickness skin grafts that is he included the epidermis He states that the epidermis atrophies and that inclusion cysts do not form Others (Massden Zavaleta et al M and A Behrend and Vasquez) have confirmed his findings. The reasons for the author's preference for the dermal graft have been given on p 42 As filling material diced-cartilage grafts (L. Peer) and foreign body material such as tantalum mesh (Koontz) and pliable plastics (Moore and Siderys) have also been suggested The foreign body meshes are known to have broken and caused considerable distress to the patient whenever he bends forward

tion of mattress sutures, compare with Fig 275, 276) The edges of the overlap flap are then sutured to the fascia, upon which they lie In longitudinal incisions, the side-to-side overlap is similar. In this way, the hernial opening is made as small as possible

A pattern is now made of the remaining defect, and a dermal graft 2 5 cm (1 inch) wider than the pattern is removed from the abdomen or one of the thighs (for technic of removal of dermal graft, see p 43 and Fig 271) The graft is placed upon the fascia surrounding the defect's edges Since the graft has been cut larger than the defect, it overlaps the defect's edges Interrupted sutures of silk are placed through the graft and the edges of the hernial defect beneath it The graft is held under as much tension as possible Then follows suture of the overlapping graft edges to the aponeurosis The overlying subcutaneous tissue and skin are coapted To facilitate an intimate contact between graft and overlying subcutaneous tissues and to avoid dead spaces, the subcutaneous-tissue sutures should include the graft surface Then follows suture of the skin edges

The technic for repair of an inguinal hernia with a dermal graft is shown in Figs 271 to 273

After-Treatment: A firm dressing is applied, and is changed after seven days, the skin sutures are removed at that time The patient is allowed out of bed three weeks after the operation

DECUBITAL ULCERS

Decubital ulcers, developing as common bedsores or from spinal injuries followed by paraplegia, may heal under conservative treatment More often, however, particularly in the paraplegic group, they may resist medical management Skin-grafting has been successful in closing these ulcers (Barker, Elkins, and Poer) A more reliable closure, with better padding of the ulcerated area, is established by the use of pedicle flaps (Croce, Schullinger, and Shearer, White and Hamm, Gibbon and Freeman, Kostrubala and Greeley, Conway, et al , Gelb, Guttman and others) Before such a closure is attempted in the debilitated patient, his general condition should be improved by local and systemic measures These include relieving pressure on the site of the lesion (placing the patient on a Stryker frame is valuable), combating infection and inflammation, establishing a positive nitrogen balance, and providing an adequate intake of vitamins The patient should be given a diet high in calories and proteins, supplemented by vitamins, together with infusions of plasma, whole blood, and amino acids It has been pointed out that a true metabolic imbalance occurs in paraplegic patients Cooper, Ryerson, et al ,

Technic (Case 90 p 966) An incision is made over the hernia if possible the former scar is excised. The hernial sac is dissected free from the surrounding structures until the fascial ring is well defined. The sac is now opened, care being taken not to injure abdominal contents, which may be adherent to the sac. The sac may or may not need removal. In the latter case, its edges can be later utilized for closure. All adhesions on the peritoneal side are severed for a distance of from 12.5 to 14 cm.

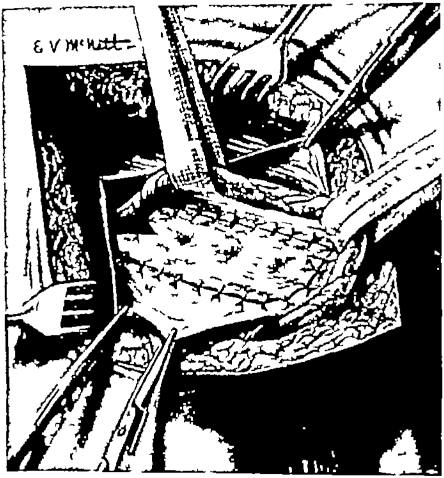

Fig. 273 Reinforcement of suture line and closure of remaining inguinal gap with dermal graft. Fascia of musculus obliquus ext. to be sutured over the graft beneath the spermatic plexus.

(about 5 to 6 inches) from the hernial ring The hernial opening is now reduced as much as possible by Mayo's overlapping method. To facilitate the overlapping of the aponeurosis a transverse or longitudinal incision is made on each side of the ring thus forming two flaps of aponeurosis. If the transverse incision is used the upper flap is pulled over the lower flap ("vest over pants") The edge of the lower (under) flap is held well drawn up to the overlap (upper) flap by mattress sutures (for inser-

The pendulous abdomen, or fat apron, however, has a different cause. It is mostly due to hyperadiposity associated with relaxation of the fasciae and muscles Hence, the operation of correction is divided into two phases: (1) transverse shortening of the fasciae and muscles, (2) excision of fat tissue and skin.

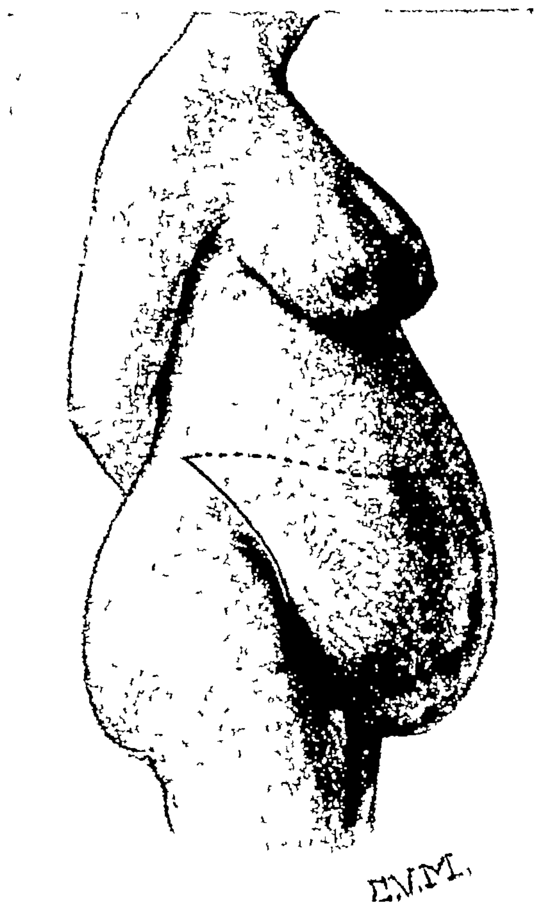

Fig 274 Plastic correction of adipose abdomen associated with relaxation of fasciae and muscles *a*· A curved incision, passing from one loin through inguinal region, mons pubis, other inguinal region to other loin, is made, penetrating skin and subcutaneous tissue Dotted line indicates base of flap of skin and fat tissue to be lifted up (E. Schepelmann)

Technic (Schepelmann) (Figs 274–277) (Case 92, p 971) A curved incision—passing from one loin through inguinal region of same side, mons pubis, and inguinal region of other side to the other loin—is made, penetrating skin and subcutaneous tissue Skin and subcutaneous fat tissue are dissected free from the aponeurosis, and a large apron of tissue is lifted to a line above the umbilicus A transverse, downward-curved incision is now made through the aponeurosis covering the abdominal muscles. The aponeurosis on each side of the incision is dissected away from the muscles, forming an upper and a lower flap. A midline incision

and Langston have counteracted this with testosterone propionate varying from 25 mg three times weekly to 100 mg once a day

The ulcer should be cleansed with hydrogen peroxide and covered with wet dressings of Dakin s or saline solution Only after the patient s general condition has been improved and the ulcerated area is covered with healthy granulations free from sloughing should the operation be performed It consists in excision of the ulcer and all scar tissue removal of underlying bony prominences—a valuable innovation made by Blocksma Kostrubala and Greeley—and closure of the defect with sliding flaps The various flaps have been outlined in detail by Croce et al and Gelb

Large sacral defects must be covered with four sliding flaps as Case 84 p 954 demonstrates Smaller defects should be closed with two flaps as demonstrated by Case 85 p 956 The two-flap method has the advantage that the suture lines do not meet in a center point over the ulcer site and thus avoids a locus minoris resistentiae In trochanteric ulcers the flap is outlined on the anterior lateral aspect of the upper thigh with its base at the femoral triangle It is shifted laterally over the resected trochanter region and the flap bed is covered with a split graft. In ischial ulcers one performs a wide resection of the tuberositas ischii and portions of the superior and inferior rami ischii and inferior rami pubi The musculus obturator internus is sutured to the cut end of the biceps and the wound is closed by simple approximation. Shifting of a flap from the posterior aspect of the thigh may be occasionally necessary

Deformities

ADIPOSE ABDOMEN

In the majority of cases the deformity of the adipose abdomen is a combination of hyperadiposity and other aggravating factors such as relaxation of the abdominal fasciae and muscles diastasis recti abdominis, or abdominal hernia. Hence reduction of skin and fat tissue would not suffice unless the other underlying conditions were corrected Schepelmann divides the adipose abdomen into two varieties, the globular and the pendulous The globular abdomen is mostly due to rectus diastasis or large umbilical hernia Approximation of the recti and longitudinal overlap of the anterior rectus sheaths followed by reduction and adaptation of the overlying subcutaneous fat tissue and skin is the operative procedure for correction of the globular abdomen due to rectus diastasis. The transverse overlap of the aponeurosis (vest over pants) and reduction and adaptation of subcutaneous tissue and skin is the method of choice in umbilical hernia (see foregoing remarks on technic in incisional hernia p 467)

If the umbilicus is to be preserved, it is circumscribed by a transverse elliptical incision as the first step of the operation. The incision penetrates to the posterior sheath of the rectus muscle. Thus, the umbilicus is left in place when the skin and upper aponeurosal flaps are lifted up The latter have corresponding elliptical holes. When the aponeurosal flaps are overlapped, elliptical holes must be cut for the reception of the umbilicus. The same holds true when the skin flap is adjusted.

Fig 276 Mattress sutures are tied Edges of overlap flap are sutured to aponeurosis upon which they lie

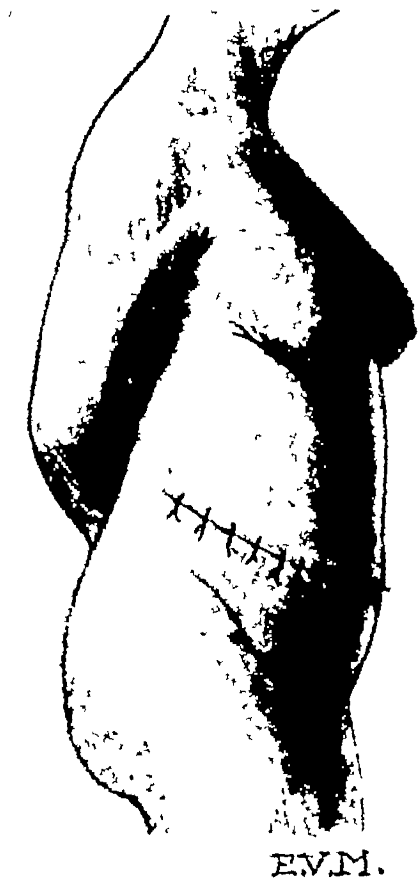

Fig 277 Skin and fat-tissue flap is reflected downward and trimmed, wound is closed in layers

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may be added above the umbilicus Any diastasis of the recti muscles is corrected at this stage by tucking the so-called middle field (posterior aponeurosis fascia transversalis, peritoneum) inward and suturing the median borders of the recti muscles together thus shortening the abdominal wall transversely The longitudinally stretched recti are shortened by pleating the muscles. The edge of the lower aponeurosal flap

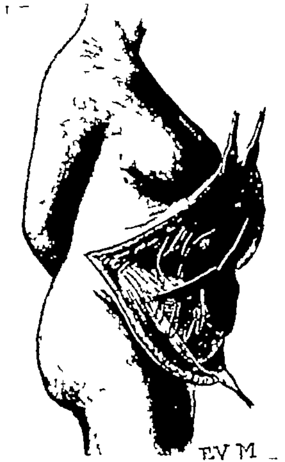

Fig. 275 Flap of skin and fat tissue is lifted up. An upper and lower flap of aponeurosis covering abdominal muscles are formed. Longitudinally stretched recti are "pleated." Edge of lower aponeurosal flap is to be lifted upward beneath upper flap. Mattress sutures are laid as in Mayo's overlap technic of hernial repair.

is now lifted upward beneath the upper flap (Above the umbilicus the aponeurosal flaps are overlapped longitudinally) The edge of the lower (under) flap is held well drawn up to the upper (overlap) flap by mattress sutures according to Mayo's overlap technic. The edges of the overlap flap are then sutured to the aponeurosis upon which they lie

The skin and fat-tissue flap is reflected downward and shortened to proper size. A drain is inserted at either lower lateral angle of the wound. and the wound is closed in layers

XVI

MAMMAPLASTIC PROCEDURES

Mammaplasty in the Female

BREASTS are deformed, according to the female patient, because they are either hypertrophic or, in rarer instances, too small. The causation in either type is not well understood, but the condition is probably the result of endocrine dysfunction. In the hypertrophic type, additional factors such as pregnancy or obesity may lead to deformity.

HYPERTROPHIC PENDULOUS BREASTS

McIndoe divides the hypertrophic forms into five types:

1. Long, heavy, pendulous breasts with hypertrophy of the most dependent glandular portion, characteristic of the adolescent girl of otherwise normal build. This is probably purely endocrine in type.
2. Broad, heavy breasts associated with obesity and aggravated by pregnancy. This is probably of more complex endocrine origin.
3. Saclike dependent breasts following reduction of obesity in Type 2 or multiple pregnancies in Type 1.
4. True gynecomastia. Marked hypertrophy of the glandular elements of the breast results in one of enormous proportions. These cases are not common, but are purely glandular in origin and related to Type 1.
5. Asymmetry.

A number of operations have been devised for reconstruction of breast deformities. Exhaustive and well-illustrated reviews of the various operations have been published by Biesenberger, by Thorek, and by Malniac. Each method has its advantages and disadvantages. Some are performed in one stage, others in two stages. The author has given a number of these methods a fair trial, and has also devised a method of his own

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ing skin but left attached to its base, a sufficient blood supply is guaranteed from beneath If, however, in addition to the skin incisions, much breast tissue needs to be removed, the deep blood supply of the areola may become insufficient unless proper precautions are taken, such as resecting only the lateral parts of the breast tissue, leaving the median half intact to form a median pedicle (Biesenberger, Gillies, and McIndoe),

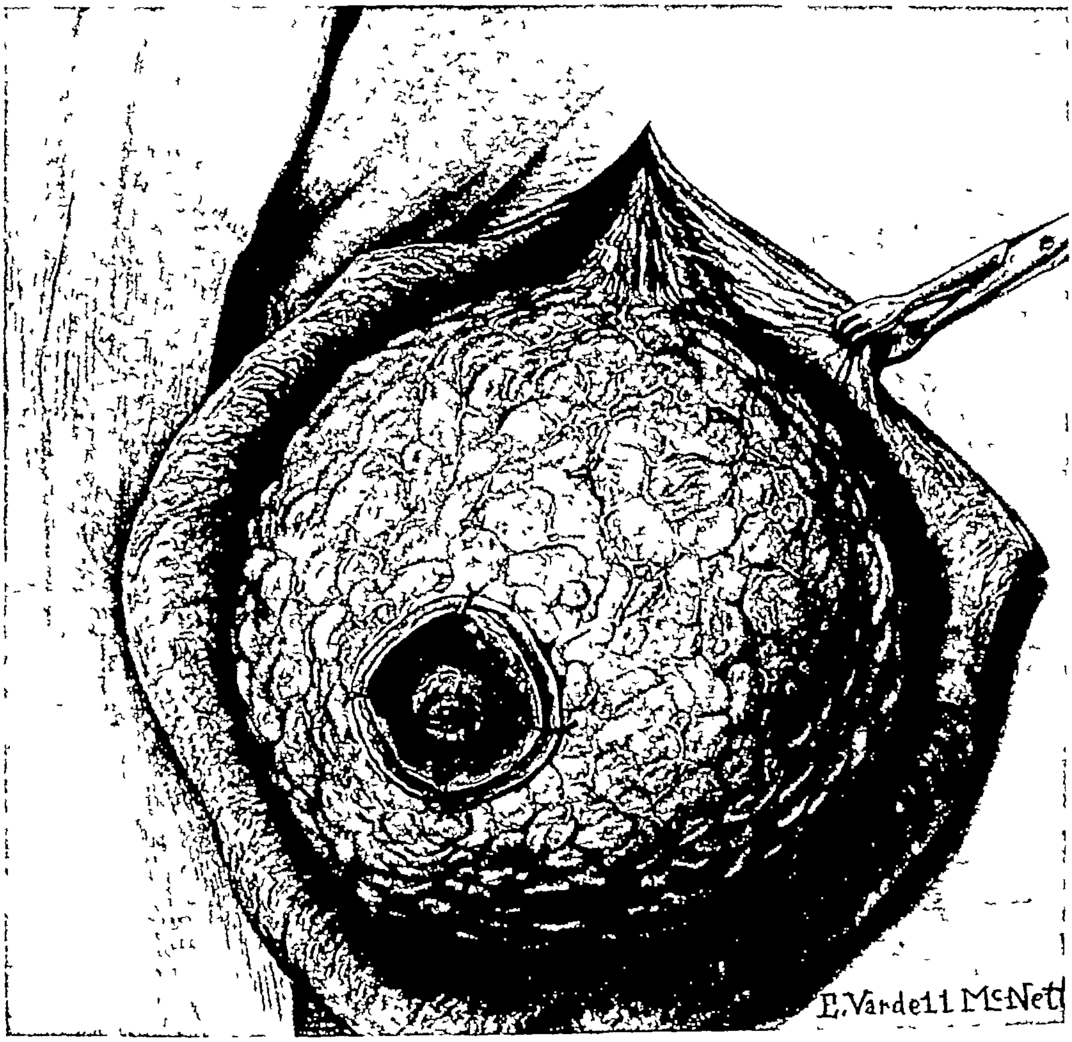

Fig 279 Skin and thin layer subcutaneous fat tissue dissected away from breast

and leaving the areola attached to a pedicle flap, which is freed from epidermis and transplanted subcutaneously (Schwarzmann) Hence, in markedly hypertrophic breasts requiring much reduction, the author advises a plastic amputation of the breast with free transplantation of the nipples (Thorek), rather than a procedure that endeavors to preserve the nipples and the function of the gland This operation can be performed in one stage The cosmetic appearance after the reconstruction

Experience however has taught him that no single procedure can be effective for all types of breast deformity In giving up his former method in preference to a simpler one (which however is applicable only for the reconstruction of medium-sized and fairly large breasts) the author has worked out a combination of certain useful features of some of the standard methods such as those of Lexer and Biesenberger This method preserves the nipples and function of the gland and can be performed in one stage Although technically it is applicable for correction of all

Fig 278 Breast plasty with preservation of function of the gland. New site of the areola is marked out (x) Areola circumscribed with an incision through partial thickness of skin a wider rim of entire thickness of skin circumscribed; areola fastened to rim of latter with holding sutures. Incision from upper pole of areola incision to x and from lower pole downward.

degrees of breast hypertrophy it is not advisable to apply this procedure in markedly hypertrophic breasts since it, like any one-stage procedure that is intended to preserve the function of the gland, endangers the blood supply to the nipple

The blood supply of the breast is derived from three sources branches of the arteria axillaris of the arteria mammaria interna and the arteriae intercostales According to Cruveilhiers Kaufman Malniac, and others the third and fourth branches of the arteria mammaria interna carry the main blood supply not only to the gland but also to the areola While the branches of the arteria axillaris supply only the lateral superficial parts of the breast the intercostal arteries are insignificant (Anson Wright and Wolfer) Thus the areola receives its blood supply from beneath—from the branches of the arteria mammaria interna and also from the surrounding skin If the areola is separated from the surround

taneously (Fig 278). An assistant now stretches the areola lightly. An ordinary medicine glass, the rim of which is painted with methylene blue, is placed over the areola, thus outlining its new size An incision is made around the inscribed circle, but is not carried through the entire thickness of the skin The skin around the areola is stretched tightly so that the subcutaneous tissue becomes exposed, this is incised about 1 2 to

Fig 281 Adaptation of wound edges of breast.

2 5 cm (½ to 1 inch) away from the original areolar incision (Aufricht), thus, when the skin is subsequently placed around the areola, the subcutaneous ring anchors it and prevents bulging and herniation A few catgut stitches through the rim and the underlying breast tissue will prevent tearing of the areola during the subsequent dissection (Fig 278). An incision is now made from the newly selected site of the nipple to

is most satisfactory A fear that this operation may lead to cystic degeneration or such other pathological changes as malignancy of the breast is unfounded particularly since most of these large breasts have little if any glandular tissue. If after such an operation the woman becomes pregnant as has happened in three of the author's patients the function of the gland can be promptly stopped by the administration of stilbestrol

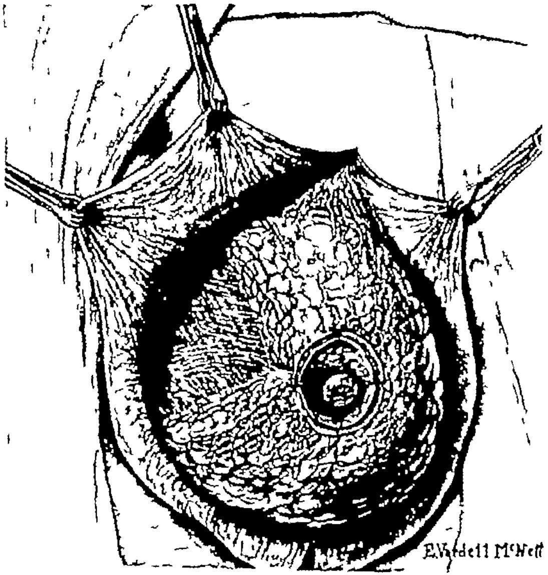

Fig. 280 Excision of wedged piece of breast tissue from lateral parts of upper and lower quadrants.

Technic (Correction of Medium Sized and Fairly Large Pendulous Breasts) (Figs 278–284 Case 78 917) The patient is operated upon in a half sitting position under endotracheal anesthesia a blood transfusion is running through a vein of the foot. The new site of both nipples is selected and marked with a drop of *methylene blue* injected intracu

special clamps, such as demonstrated in Fig 282 The lowest clamp should be placed not at the base of the breast but about 2 5 cm (1 inch) above the mammary fold A running wire mattress suture is temporarily laid just beneath the clips, and the latter are then removed The redundant skin is now excised in front of the wire suture, and the skin edges are sutured together with interrupted nylon sutures The lowest

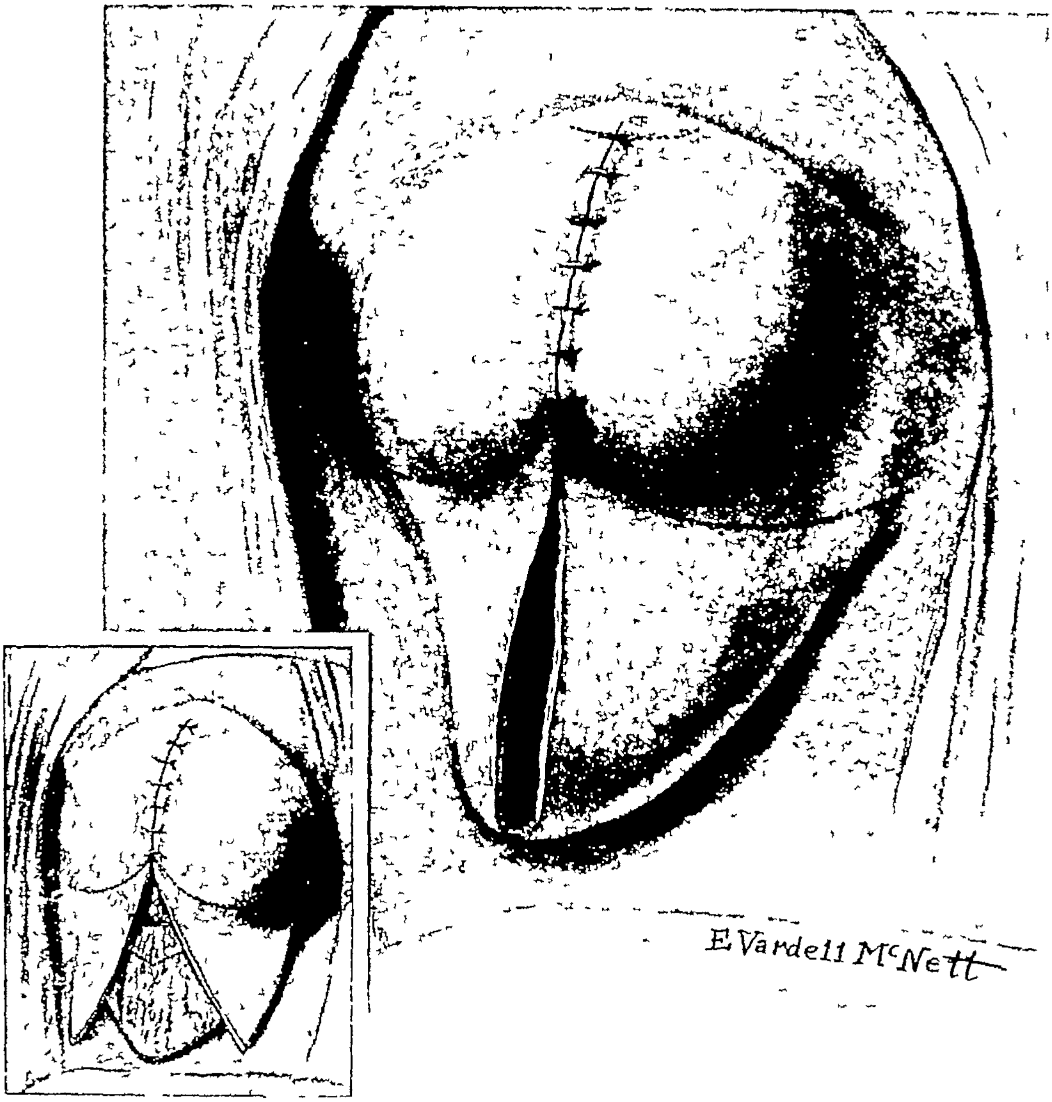

Fig 283 Curved incisions outlined for formation of narrow triangular flap beneath breast

suture is about 2 5 cm (1 inch) away from the base of the breast The wire suture is now removed From the points of the lowest suture, a curved incision is made laterally and medially A triangular flap is made, as outlined in Fig 283, *inset*, with its base along the mammary fold It is trimmed to fit into the remaining triangular defect at the base of the breast This triangular flap affords a good support The patient is now

the upper pole of the areolar incision and from the lower pole two-thirds of the distance between nipple and mammary fold (Fig 278) The skin and a thin layer of subcutaneous fat tissue are now dissected away from the breast, mostly by blunt stripping until the whole body of the breast is developed (Fig 279) A wedge-shaped piece of tissue is removed from the upper and lower lateral quadrants The wound edges of the breast

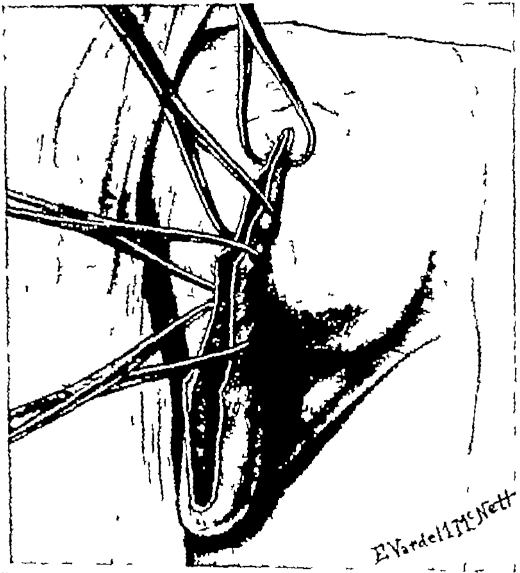

Fig. 282 Skin draped around breast, areola temporarily buried lines of excision of redundant parts outlined.

tissue are approximated with a few sutures (Figs 280-281) The patient can now be changed from a half-sitting to a more horizontal position to facilitate the following steps The skin is then draped around the breast like a brassiere (Fig 282) Thus the nipple becomes temporarily buried beneath the skin The skin is held snugly together with towel clips or

After-Treatment A firm, uplifting pressure dressing is applied to both breasts The drains are removed on the third day, preferably without disturbing the remainder of the dressing The sutures are removed on the eighth postoperative day.

Technic (Mammaplasty for Large Pendulous Breasts with Free Transplantation of the Areolae) (Figs 285–288, Cases 79, 80, pp 948, 949). Thorek excises the areola and transplants it at the beginning of

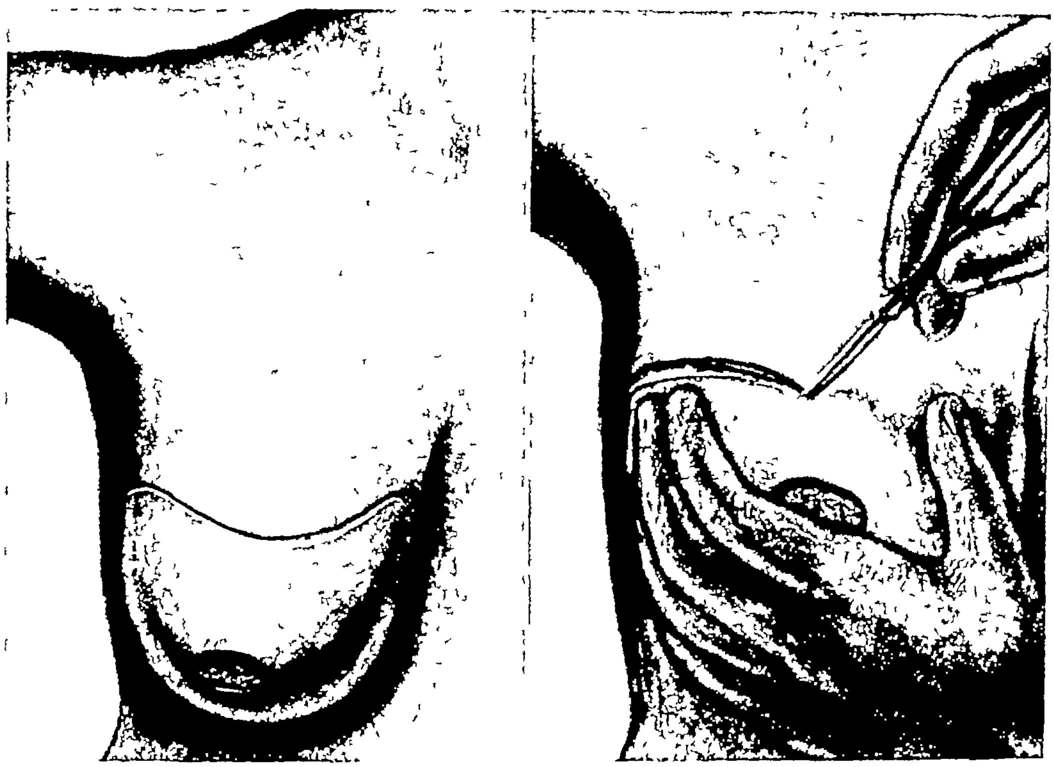

Fig 285 Fig 286

Figs 285-286 Plastic correction of breasts (Thorek) Fig 285 Heavy line indicates anterior incision Areola is excised as free graft Fig 286 Redundant parts of breast are excised from anterior incision.

the operation Adams, however, points out correctly that one should select the new site for the areola at the end of the operation, since only after the partial amputation and reshaping of the breast is an accurate estimate possible The author agrees also with Adams that both sides should be operated upon at one sitting

The patient is operated upon in a half-sitting position under general anesthesia The areola is stretched by an assistant, who squeezes the breast between his two hands The areola is now excised like a full-thickness graft, the operator carefully avoiding any subcutaneous or fat tissue Near the nipples, the dissection is gradually made deeper in order to obtain some of the smooth-muscle tissue The areola is carefully

placed again in a half sitting position and the same procedure is performed on the other side. The final step is the excision of skin over the buried areola and the adjustment of the areola to the wound edges. The possibility of rechecking and adjusting the new site of the areola at the end of the operation is a definite advantage of this procedure over methods in which the areola is sutured into the new position at the

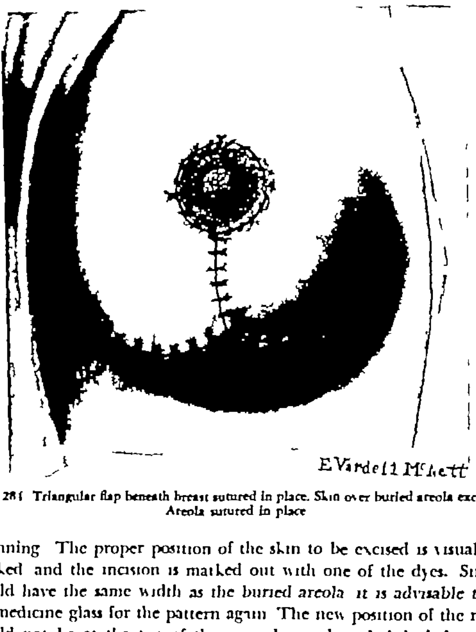

Fig. 281 Triangular flap beneath breast sutured in place. Skin over buried areola excised. Areola sutured in place

beginning. The proper position of the skin to be excised is visually rechecked and the incision is marked out with one of the dyes. Since it should have the same width as the buried areola, it is advisable to use the medicine glass for the pattern again. The new position of the nipple should not be at the top of the conic breast but slightly below. The marked-out skin is now excised and the areola drawn out and sutured to the wound edges (Fig. 281). A drain is inserted into each lateral wound corner.

extreme cases, an additional pleat may be excised from the lateral portion A drain is placed into the lateral wound corner

The new site to which the areola is to be transplanted is selected, and marked out with one of the aniline dyes The host area should be made slightly smaller than the areola graft, since there always occurs some immediate shrinkage of the graft The skin of this circular host area is dissected away as with a thick split graft, leaving a thin basal layer of derma behind The subcutaneous fat tissue should not be exposed, since adipose tissue is not as well vascularized as the derma of the skin The previously excised areola is transfixed with a straight needle, and carefully sutured in place with a continuous suture of fine silk on an atraumatic needle

The same procedure is performed on the other side

After-Treatment A firm pressure dressing is applied over the transplanted areola as follows one piece of bismuth tribromophenate (xeroform) gauze over the areola, followed by a thick piece of rubber sponge larger than the areola and "saucerized" where it comes to lie over the nipple The dressing is held in place with adhesive strips The other part of the dressing is applied as previously described (p 482) The pressure dressing over the grafts should not be changed for at least ten days, unless there is evidence of infection, while the other part of the dressing is changed and the drains are removed on the third day.

SMALL BREASTS

Indications for reconstructive operation in small breasts are smallness of breasts due to removal of breast tissue (cystic mastopathia, tumor) and genuine small breasts (hypomastia). Czerny, as far as can be ascertained, was the first to perform a reconstructive operation for correction of a small breast For an actress, from whom cystic tissue of the left breast had been removed, he replaced the tissue by a lipoma from the patient's lumbar region The breast remained well formed, and the lipoma did not grow.

If the breast deformity is unilateral, as it may be in congenital or postoperative cases, the larger breast may be reduced by mammaplasty and some of the resected tissue transplanted into the smaller breast If this is impossible, a dermal-fat tissue graft should be used In genuine small breasts (hypomastia), hormone treatment should be given a trial (Macbryde) If it fails, a dermal-fat tissue graft should be transplanted The graft is preferably taken from the region of the gluteal fold (Winkler and others) It is advisable to take the graft two-thirds larger than required, to counteract degeneration and shrinkage Others (Long-

wrapped in gauze wet with isotonic saline solution care being taken that the solution is not hot or even warm The graft, wrapped in the gauze is laid on a separate instrument table as a precaution against its being discarded. An anterior horizontal semicircular incision is made from which the redundant parts of the breasts are to be removed The incision is downward and convex with its extremities rounded. A line connecting the two extremities of the incision should be on a level with the mam

Fig. 287

Fig. 288

Fig. 287 Posterior incision is made parallel with mammary fold, 2.5 cm. (1 inch) above latter Fig. 288 Breast is shaped. Skin edges are sutured. Site where areola is to be transplanted is denuded so that only part of thickness of skin is removed, leaving derma behind. Areolar graft is laid upon raw surface and sutured in place.

mary fold on the posterior side of the breast. The breast is now elevated and an incision is made on the posterior side parallel to and about 2.5 cm (1 inch) above the mammary fold. The skin edges are undermined along the anterior and posterior incision The redundant mammary tissue is now excised and the remainder is shaped and inverted with heavy catgut sutures Invariably the anterior wound edge of the skin is longer than the posterior one. One can overcome this discrepancy either by reefing the anterior wound edge when suturing—in spite of the resulting irregularity the scar as a rule smooths out—or by pleating the anterior wound edge by excising a triangular piece of skin from the central portion. In

nipple) The edges of the elevated flap are sutured together, thus continuing the tubed pedicle Two weeks later, the abdominal end of the flap is severed gradually. A few days later, the flap is partly opened out and sutured into the place prepared for it In the third and last stage, three weeks after the transfer of the flap, the pedicle is severed and discarded

LOSS OF AREOLA

Loss of the areola is more often due to impairment of circulation after mammaplasties than to trauma, such as burns If replacement is warranted, the Adams method appears feasible He used the skin of the labium minus, which is picked up with a thumb forceps and clipped off with a pair of scissors, as a free graft This skin is brownish and has a rough surface, and is thus most suitable to replace an areola

INVERTED NIPPLES

Pfaundler distinguishes two varieties of inverted nipples the genuine and the spurious form The former is considered to be a developmental hypoplasia so far as the nipple failed to grow forward above the plane of the areola The spurious form is due to hypertrophy of the muscles of the areola which hold the nipple back Hence, in the first form, the nipple is not developed or at least not sufficiently developed, in the second form, the nipple is well-built, but hidden behind the areolar muscles. Inverted nipples not only are a deformity but may also lead to inflammatory processes of nipples and breast and may make nursing difficult or impossible Hence, operative correction may become necessary Sellheim, improving Kehrer's and Barth's procedures, devised a good method, which is carried out as follows·

Technic (Sellheim) (Fig 289) The incisions are outlined with one of the aniline dyes, as illustrated in Fig 289, *2* The long horizontal incisions are made first, and should penetrate the entire thickness of the skin The smaller radial incisions and the circular incisions are then added (Fig 289, *3*) The nipple is now grasped with a traction suture and pulled forward The entire areola is circumscribed with an incision which should reach the smooth muscle layers While the nipple is held under constant pull, the skin of the areola is severed with circular incisions from the muscles (Fig 289, *4*) Some of the muscle bundles, whenever restricting, should be divided Galactophorous ducts and major vessels, however, should not be injured. Dissection is best carried out with the knife blade directed vertically to and not parallel to the base,

acre, Gohrbandt) recommend the use of subcutaneous flaps as filling material

Technic (Case 81 p 950) The dermal fat tissue grafts are taken first. With the patient lying on her abdomen and the table tilted so that the patient s legs are dependent in a position similar to the Kraske position for rectum amputation the graft area is marked out as an ellipse with the gluteal fold forming the axis The epidermis can be removed now with the dermatome or later with an ordinary transplantation knife after the graft has been excised The graft consists of skin (derma) and fat tissue. After the grafts are removed the foot end of the table is straightened and the wounds are sutured with through and through mattress sutures of wire or heavy silk The patient is turned around and the breasts are aseptically prepared From an incision in the mammary fold the breast is separated from the pectoral fascia until a large cavity between breast and pectoral fascia is created After thorough hemostasis the graft is placed into the pre pared cavity of the breast in such a way that the dermal side of the graft comes to lie against the pectoral fascia. The wound is now closed in layers

The same procedure is performed on the other side in the same sitting

After Treatment Moderate pressure is applied to the breasts with a figure-of-eight dressing around breasts and shoulders Dressing and su tures of the breasts are removed on the seventh day while the sutures at the thigh remain until the tenth day

TRAUMATIC ASYMMETRY

After mastectomies or destruction of the breasts from burns, the patient may be unduly self-conscious of the asymmetry in spite of shield ing with a foam rubber prosthesis. Gillies also Holdsworth devised a rather simple technic for replacing the mammary prominence The method consists in transferring the circumumbilical skin and fat pad by means of a tube pedicle to form the new prominence The umbilicus is turned out to form the new nipple.

Technic (Gillies) Three stages and one substage are required *In the first stage* a tube flap is constructed on the affected side similar to the thoracoepigastric tube flap described on p 88 It starts in the midaxillary line at the level of the sixth rib Its direction is toward the abdominal prominence which surrounds the umbilicus In a substage *two weeks later* the circumumbilical fat pad is elevated except for 5 cm (2 inches) on its far side The umbilicus is freed and everted, and the hollow be neath it is filled out by gathering small fat pads from the neighborhood and suturing them together (As an alternative method Gillies recom mends burying a firm substance such as cartilage beneath the everted

Mammaplasty in the Male

Mammaplasty in the male is performed in cases of benign gynecomastia Conservative treatment, such as irradiation and endocrine therapy, fails as a rule to reduce the enlarged breast Surgical treatment offers

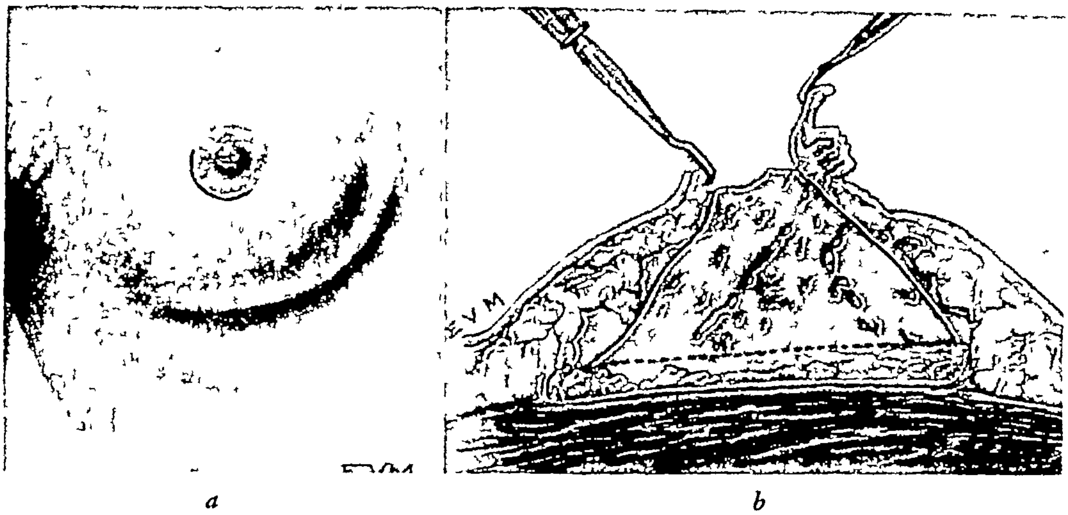

Fig 290 Breast plasty for gynecomastia after Webster *a* Semicircular incision just within pigmented area of areola *b* Areola dissected away from ducts and glandular tissue Lines of conic excision of breast tissue marked with heavy lines, broken line indicates separation of base of breast with amputation knife inserted through separate incision below breast

the greatest promise, and eliminates the threat of subsequent malignant changes and the development of psychic trauma The author is familiar with the operation devised by J Webster, and has found it very satisfactory A slight modification facilitates the removal of the breast tissue

Technic (J. Webster) (Fig 290, Case 82, p 952) The operation is performed under general anesthesia If both sides are involved, they are operated upon in the same stage The areola is distended by pressure, and a semicircular incision is made just within the margin of the pigmented area of the areola The areola is dissected away from the underlying ducts and glandular tissue Traction is now applied on the divided ductal stumps, and a cone-shaped piece of breast tissue is dissected away from the subcutaneous fat tissue partly under blunt and partly under sharp dissection Enough adipose tissue must be left behind to be drawn eventually beneath the areola Bleeders should be clamped and ligated To facilitate separation of the conic breast tissue from the pectoral fascia, the author makes a small incision at the lower base of the breast, and inserts an amputation knife between the base of the breast and the pec toral fascia, upon which a layer of fat tissue should be left attached (see

and proceeds until the everted nipple and adjacent skin look like a folded umbrella.

Excision of small triangles of skin from the edges of the areola and subsequent suturing of those defects shorten the circumference of the areola and prevent retraction of the nipple (Fig 289, *5 6*) Fig 289 *6*, shows the tightening of the collar around the neck of the nipple.

With silk sutures, the wound margins of the everted areola are now united with those of the surrounding skin The first suture is placed

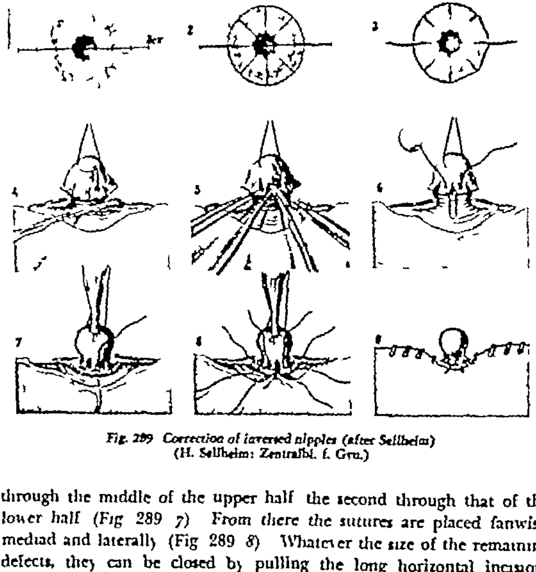

Fig. 289 Correction of inverted nipples (after Sellheim)
(H. Sellheim: Zentralbl. f. Gyn.)

through the middle of the upper half the second through that of the lower half (Fig 289 *7*) From there the sutures are placed fanwise mediad and laterally (Fig 289 *8*) Whatever the size of the remaining defects, they can be closed by pulling the long horizontal incisions together with sutures (Fig 289 *9*)

Spina covers the denuded area around the nipple i e the denuded areolar region with a skin transplant from the labium minus (see p 486) thus avoiding deformities from suturing of the horizontal incisions.

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dotted line in Fig 290 *b*) With the left hand held against the breast as a protecting measure and with pull exerted on the breast tissue the breast tissue is now severed from its base with long sweeps of the amputation knife. Pull should be relaxed before severing the central part to avoid removal of too much tissue where the areola will come to lie. The cone shaped tissue is pulled through the opening at the areola it may need halving or quartering if the tissue is too large to be drawn in toto through the opening at the areola. After thorough hemostasis the wound is closed in layers. This is one of the most difficult phases of the operation. To prevent the nipple from becoming adherent to the underlying fascia sufficient fat tissue must be sutured together, often by a trial-and error method After this is accomplished the areola wound is closed If the edges of the areolar flap look devitalized through pressure of the retractors débridement of the devitalized rim should be performed first. A drain is inserted into the small wound through which the amputation knife was inserted and a heavily padded pressure dressing is applied It is changed after five days and drain and sutures are removed

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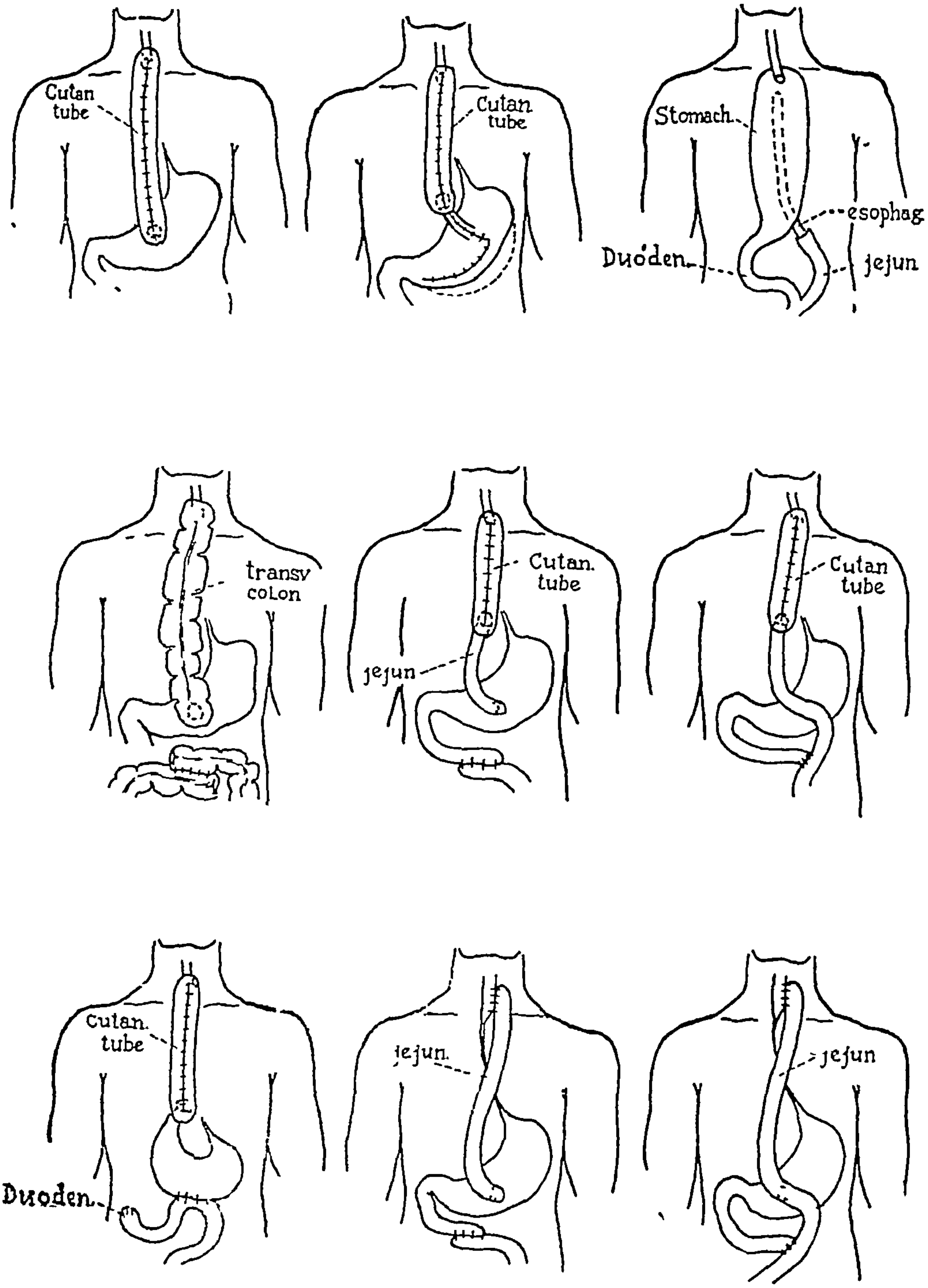

Fig 291, *a* Various procedures of extrathoracic esophagoplasty (S S Yudin Surg, Gynec & Obst.)

XVII

CONSTRUCTION OF ESOPHAGUS

An esophagus is constructed for reestablishing deglutition in patients suffering from cicatricial atresia of the esophagus following chemical burns in the treatment of neoplasms and congenital tracheoesophageal fistules This can be achieved in various ways either via the extra thoracic or intra-thoracic route. The direct replacement of the esophagus with a plastic tube (after Berman) is the latest innovation

Construction of Extrathoracic Esophagus

SURVEY OF PROCEDURES

Various procedures have been recommended to connect the cervical part of the esophagus in an extrathoracic manner with the stomach (Fig 291) Bircher (1894) was the first who attempted to circumvent a malignant stricture of the esophagus with an antethoracic skin tube, which was to connect the stomach with the cervical part of the esophagus. He could not complete the operation since the patient died from a pulmonary embolism Wullstein (1904) from cadaveric studies suggested the first jejunodermatoesophagoplasty He severed the jejunum a short distance below the ligament of Treitz the proximal loop of the jejunum was anastomosed to the distal part about 30 cm (11¾ inches) below the division with an end to-side anastomosis. The distal part of the jejunum above the anastomosis was pulled through the mesocolon lesser sac, and gastrocolic omentum led in front of the stomach and through a subcutaneous tunnel anterior to the thoracic muscles, until its end was made to escape through a small skin incision at the level of the cartilage of the sixth rib In a second operation he suggested formation of a skin tube which was to connect with the jejunal opening and to reach the

Lexer, in 1911, published his first successful case of jejunodermatoesophagoplasty. He excluded the upper jejunal loop, displaced it antecolicly, anastomosed it end to side with the anterior surface of the stomach, and led it subcutaneously anterior to the thoracic muscles upward In a second stage, he formed the skin tube and joined it with the jejunal opening, in a third stage, the esophagus was opened laterally and the opening sutured into the cervical skin wound. In a fourth stage, the upper end of the skin tube and the cervical opening of the esophagus were joined Lexer's reason for making a lateral opening in the esophagus instead of transversely sectioning it was twofold (1) to lessen the danger of mediastinitis from the retracting distal end of the severed esophagus; and (2) to prevent stagnation of esophageal secretion in the blind section (Fig 291, *a* [center], and Fig 292)

Since that time, various other suggestions have been made Ochsner and Owens published an exhaustive and critical review of the literature up to 1934 and presented their own case, the first successfully completed jejunodermatoesophagoplasty recorded in America Davis and Stafford in 1942 added valuable information Since then, additional articles have been published and modifications recommended (Longmire and Ravitz, Stevenson, Watson and Converse, Ivy and Hawthorne, Hardin, Ashley, et al) Axhausen reported a long term follow-up examination of three patients with total esophagoplasty

In 1944, Yudin of Moscow published his enormous experience of eighty-eight completed antethoracic esophagoplasties Of these eighty-eight cases, twenty-one were total intestinal esophagoplasties, the remainder jejunodermatoesophagoplasties The total intestinal esophagoplasty is, of course, the ideal method. The whole operation can be accomplished in two stages But, as Yudin states, the procedure can be very difficult, very risky, or absolutely impossible owing to excessive fat in the mesentery, shortness of the mesentery, or particularly unlucky disposition of the radial vessels and of the mesenteric arcades If this is the case, the plan of total intestinal esophagoplasty should be abandoned and replaced by jejunodermatoesophagoplasty.

JEJUNODERMATOESOPHAGOPLASTY

Technic (after Lexer) (Fig 292) *Stage 1* The abdomen is opened from an upper paramedian incision through the left rectus muscle. Unless a gastrostomy has been already made, it is performed now on the left side and the gastrostomy tube led out of the abdomen pararectally on the left side. Then the proximal loop of the jejunum is located and severed 10 to 12 cm (4 to 4¾ inches) from the ligament of Treitz.

sternoclavicular joint. In a third operation he suggested severing the cervical part of the esophagus and connecting its proximal part with the skin tube. In this way the food would pass through the jejunum but not through the stomach.

Roux in 1907 was the first to demonstrate a successful case of jejuno-esophagoplasty He mobilized a loop of jejunum displaced it antecolicly anastomosed one end to side with the anterior surface of the stomach and led the other end through a subcutaneous tunnel in front of the

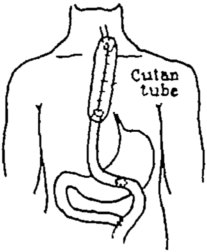

Fig. 291 b

thorax to the suprasternal notch where he left it subcutaneously The afferent and efferent ends of the abdominal jejunal loops were anastomosed side to side with each other In a second operation the proximal end of the displaced jejunal loop was anastomosed with the mobilized esophagus.

Herzen (1907) following Roux's suggestion improved the method by first leading the mobilized proximal end of the efferent loop through a slit of mesocolon and gastrocolic omentum in front of the stomach thus shortening the distance and preventing torsion of the pedicle second by excluding the jejunal loop unilaterally—suggestions previously made by Wullstein. While the latter did not join the jejunum with the stomach, Herzen anastomosed the mobilized jejunal loop with the stomach by an anterior side-to-side anastomosis.

F Torek (1913) utilized the greater curvature of the stomach to form an esophagus and Kelling (1911) and von Hacker (1914) a loop of colon and a skin tube Orsoni and Toupet (1950) reported the first successful case of an antethoracic cervical esophago-colostomy

the thoracic muscles and somewhat to the left of the midline, for a distance equal to the length of the isolated jejunal loop. The tunneling is best done by pushing a Graser or Payer type of gastric clamp upward beneath the skin and then opening the branches The jejunal loop is now laid upon the undermined skin and a small transverse incision is made through the skin on a level with its upper end From this perforation, a Kelly clamp is passed through the tunnel, the pursestring suture of the closed jejunal end is grasped, and the jejunal loop passed through the tunnel and through the upper small incision, where it is sutured to the skin without opening it.

Stage 2· About four weeks following the first operation, after all wounds have healed, the skin tube is formed and connected with the jejunum (Fig. 293)

Two parallel incisions, 8 cm (3 inches) apart, are made on each side of the proximal end of the jejunum, leading upward, somewhat toward the left from the midline, and ending from 3 to 5 cm. (1$^3/_{16}$ to 2 inches) above the left sternoclavicular junction. Below the level of the closed jejunal end, the incisions approach each other gradually (Fig 293) Between these two parallel incisions, skin, subcutaneous tissue, and deep fascia of the median margins are undermined one third until a lateral and a median skin flap is made for the formation of the skin tube A broad base must be left attached to insure sufficient circulation in the flaps. The flaps are sutured together with silk sutures, which are tied on the inside (Fig 293) A second row of No 00 chromic catgut sutures approximates the subcutaneous fat tissue and fascia at the outside over the first row (A good suggestion is to form the flaps eccentrically, one broader than the other, which will avoid placing the suture line directly beneath the future skin suture line) Before the distal part is completed, the jejunum is opened at its exit from the skin. The skin tube is now connected with the jejunal opening, as depicted in Fig 293

To cover the raw areas on and around the skin tube, one of three procedures is available (1) mobilization of skin and subcutaneous tissue on each side of the raw areas until the wound edges can be shifted over the skin tube, (2) skin-grafting, or (3) transplanting a tube flap which in a previous stage must be constructed (a valuable suggestion of Ivy) The first method is given preference, but only if the undermined skin portions are freely movable so that there will be no tension on the suture lines To facilitate mobilization, relaxation incisions along the anterior axillary lines may be necessary (Fig 293) If this is the case, the resulting secondary defects along the anterior axillary lines may be narrowed by skin-sliding or closed by skin-grafting (Fig 293) after healing If, how-

Both ends are closed in the usual way The pursestring suture of the efferent end is left long for later use. The next step consists in mobilizing and lengthening the efferent loop of the jejunum by ligation and separation of some of the vascular trunks in the root of the mesentery while the peripheral arcades are carefully preserved The vessels should be severed only after they have been compressed with an elastic clamp and no changes in color peripheral to the compression have been observed

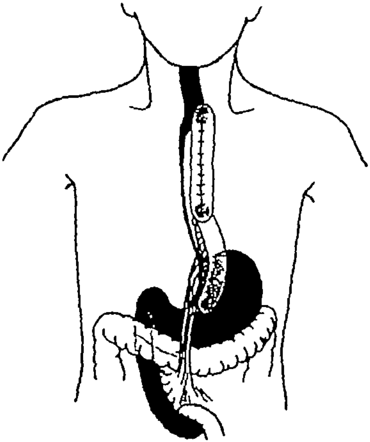

Fig. 292: Diagram of Jejunodermatoesophagoplasty (Lexer)

After the jejunal loop has been lengthened sufficiently but not unduly its distal end is divided thus the mobilization and isolation of the intestinal loop are completed The immobilized afferent and efferent jejunal loops are joined by a side to-side anastomosis (Fig 292)

The isolated loop is now displaced upward either antecolicly (Fig 292) or if the omentum is heavy retrocolicly through a slit in an avascular field of the mesocolon and gastrocolic omentum the open distal end of the loop is anastomosed end to side to the anterior surface of the stomach near the middle of the lesser curvature (Fig 292) From the upper edge of the abdominal incision the skin is tunneled anteriorly to

Fig 294 In third stage of procedure, cervical part of esophagus has been mobilized and sutured to skin wound at left side of neck In fourth stage, as depicted in this drawing, esophageal opening has been connected with skin tube, either by simple lengthening and closing of skin tube over it or by swinging an envelope flap downward (compare with *insert,* Fig 293) (See also former figure, upper part of skin tube, *x* at lateral part of neck indicates point where esophageal opening is to escape) To close raw surface at neck, two flaps are made, as outlined They are shifted over raw surface (see *insert).* The secondary raw surfaces resulting from shifting the flaps are skin-grafted

method is possible The flaps to be used are those outlined for closure of the junction at the neck (Fig 294) At this stage, the gastrostomy is kept open on bottle drainage to prevent any regurgitation of gastric juice while the wounds are healing.

Stage 3: About two months following the last stage, after all wounds have healed, the esophagus is mobilized A longitudinal incision is made on the left side of the neck, starting at the level of the upper border of the

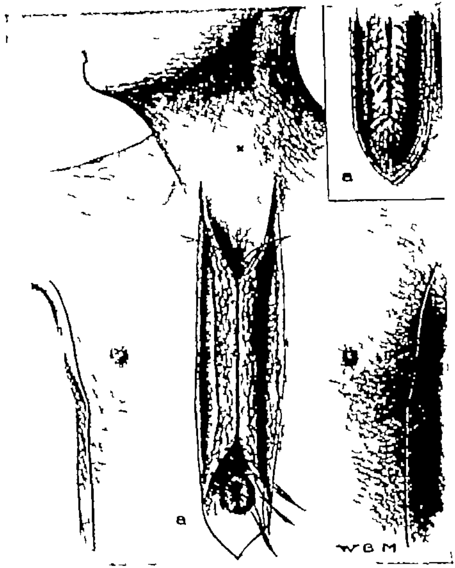

Fig. 293 Drawing depicts second stage of procedure four weeks after upward displacement and gastroanastomosis of jejunal loop. Upper end of jejunal loop where it escapes through chest wall is opened *(a)* Skin tube is made by inverting skin edges of lateral and median skin flaps. Lower end of tube is connected with jejunal opening by forming a small pointed lower flap and hinging it upward like an envelope flap *(insert)* Raw surfaces are covered by skin-sliding. Longitudinal incision in preparation for skin-sliding is depicted on left and right sides of patient. Lateral secondary defects resulting from skin-sliding are covered with skin grafts (see Fig. 294)

ever there is the slightest tension skin sliding is abandoned and skin grafts are used to cover the raw areas on and around the skin tube. With the plasma-contact method of Sano available (see p 35) thick split grafts are glued to the raw areas. This method does not require dressings. Hence the usual pressure dressing to hold the grafts firmly in place becomes unnecessary a definite advantage of course in this particular case The distal end of the tube however where it joins the jejunum should preferably be covered with pedunculated flaps unless the skin-sliding

TOTAL JEJUNAL ESOPHAGOPLASTY

Technic (Fig 295) Yudin modified the Roux-Herzen type of replacement of the esophagus by a loop of the jejunum The principle of this method is the mobilization of a long loop of jejunum (not anastomosed with the stomach), which is drawn through a subcutaneous antethoracic tunnel, and anastomosed with the cervical part of the esophagus The main advantages of omitting the anastomosis between stomach and jejunum

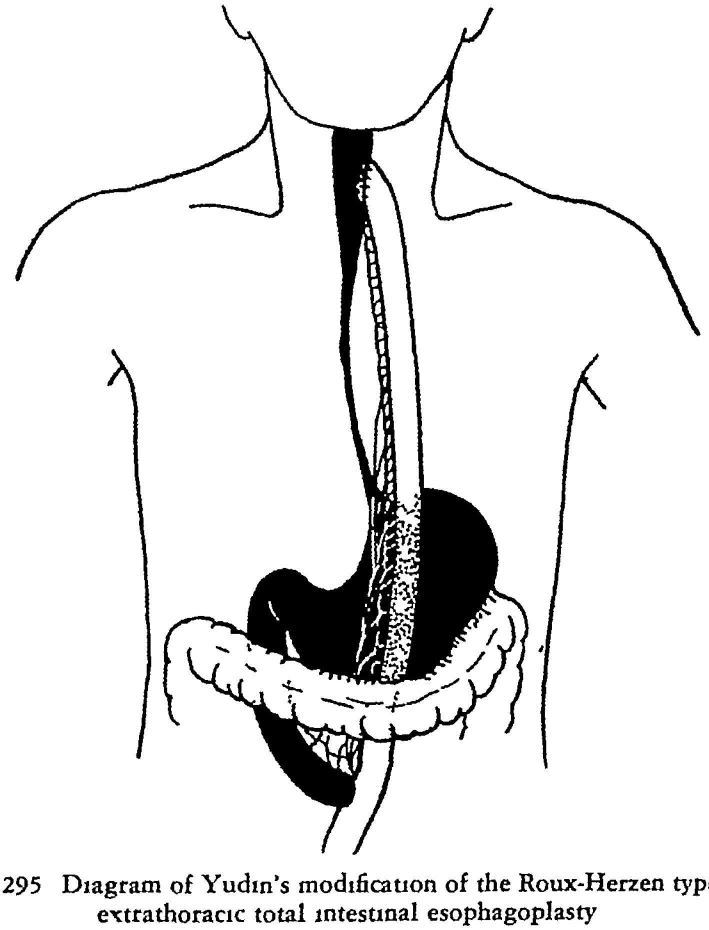

Fig 295 Diagram of Yudin's modification of the Roux-Herzen type of extrathoracic total intestinal esophagoplasty

are the simplification of the first step of the operation and the better motility of the jejunal loop According to Yudin's experience, exclusion of the stomach had no ill effects on the patients The method is possible only if a sufficiently long, viable loop of jejunum can be obtained

Stage 1. The approach to and separation of the jejunum below the ligament of Treitz are accomplished as previously described in Lexer's procedure. The efferent (distal) jejunal loop is closed in typical manner—the pursestring suture left long for later use—and lengthened by ligation and separation of its mesenteric vascular trunks Over each trunk, the peritoneal layer of the mesentery is severed in an arch-shaped line

left thyroid cartilage and leading downward toward the opening of the skin tube. From this incision the anterior border of the musculus sternocleidomastoideus is exposed and retracted laterally After incision of the deep cervical fascia the carotid sheath is exposed—but not incised—and retracted laterally The musculus sternothyreoideus and musculus sternohyoideus are incised thus exposing the lateral border of the thyroid gland The superior thyroid artery is ligated and severed, and the thyroid gland retracted medially With blunt dissection, the esophagus is now located behind the trachea, anterior and somewhat to the left of the cervical spine, and mobilized.

The question now arises whether (1) to divide the mobilized esophagus transversely closing the distal end blindly with a two-row suture and suturing the proximal lumen into the skin wound, or (2) to make an opening into the lateral wall and suture the opening into the skin wound. Each method has advantages and disadvantages. The disadvantage of the former method is possible accumulation and retention of secretion in the lower blind segment with possibility of rupture and the higher chance of mediastinitis The disadvantage of the latter is the diverticulumlike formation of the lower pouch. Lexer originally advocated the lateral opening but also has used the transverse sectioning in later cases (unpublished) The choice of the method depends mainly upon the motility of the cervical esophagus In either case the esophageal opening is sutured into the skin wound and the wound closed in layers

Stage 4 The connection between the upper end of the skin tube and the esophageal opening should be made only after the latter has well healed without evidence of stenosis. The skin tube is lengthened by continuing the two original parallel incisions upward on each side of the esophageal fistula above the level of the fistula the incisions approach each other gradually two flaps are raised inverted and sutured together as previously described ending proximally in a small blind pouch above the fistula or the upper end is closed by swinging an envelope flap downward (compare with Fig 293 *insert*) thus avoiding the blind pouch To cover the raw areas and to provide sufficient protection of the anastomosis, two lateral flaps are made which if pulled together will cross the tube obliquely (Yudin) (Fig 291) The secondary defects are either covered with skin grafts (Fig 291 *insert*) or closed or at least narrowed by undermining the lateral wound edges shifting the wound edges mediad and suturing them to the cervical fascia (not to the free edges of the flaps!)

Stage 5 Closure of the gastrostomy opening should be performed only after deglutition through the newly formed esophagus is well established.

Stage 2. Anastomosis of the closed cervical end of the jejunum with the esophagus is performed after all wounds have healed From an incision along the anterior border of the left musculus sternocleidomastoideus, the esophagus is exposed as previously described From the same incision and more lateral to it, the blind end of the jejunal loop is located and carefully mobilized Jejunum and esophagus can be anastomosed in one of three ways (1) side to side, (2) end of the jejunum to side of the esophagus, (3) end of the esophagus to side of the jejunum Yudin recommends the side-to-side anastomosis whenever possible. The anastomosis is performed similarly to any other intestinal anastomosis, and the wound is closed

If, owing to shortness or retraction of the jejunal loop or to the high level of the esophageal obstruction, the intestine cannot be joined with the esophagus directly, the opening of the esophagus and that of the jejunum are sutured into the skin wound In a third stage, both are joined by a skin tube, which is constructed similarly to, but much shorter than, the one described The raw surfaces are covered with two flaps, as outlined in Fig 294

Stage 3 Closure of the gastrostomy opening should be performed only after deglutition, through the newly formed esophagus, is well established

INTRATHORACIC ESOPHAGOPLASTY

The intrathoracic route of esophagoplasty at first approached hesitantly is becoming more and more popular since the great advances that have been made in the fields of anesthesiology and chest surgery Of the three sections of the intestinal tract which have been used for replacement, i e, stomach (Adams and Phemister, Garlock, Sweet), jejunum (Rienhoff, Harrison, Robertson and Sarjeant, Johnson, Schwegman and Kirby, and others), colon (Kergin, Mahoney and Sherman, Dale and Sherman, Neville, Smith, and Storer, and others) a loop of the transverse colon appears to gain preference for replacement of part or the entire esophagus The anastomosed stomach has caused peptic esophagitis and regurgitation of gastric contents into the pharynx The jejunum has a variability of blood supply, which may become insufficient in jejunal loops used for high esophageal anastomoses The transverse colon has an excellent blood supply and is of sufficient length to reach the neck Neville, Smith, and Storer emphasize that careful dissection of the middle colic artery and vein down to their origin from the superior mesenteric vessels and division of the mesentery in such a manner as to preserve the marginal vessels will assure viability of the bowel They outline the general technic as follows

The trunks must be freed as far as possible and as near as possible to the root of the mesentery This dissection requires ligation and separation of smaller vessels Only after the main trunks are well dissected are they ligated and severed The steep peripheral vascular arcades will now stretch out lengthwise. Each large trunk is treated in the same way however, one should test the adequacy of the circulation before denuding and separating the next trunk by clamping it with a soft clamp If clamping does not result in impairment of circulation in the peripheral arcades the vessel is ligated and severed. If sufficient length is established so that the blind end of the jejunum reaches the left mastoid process the afferent (proximal) jejunal loop is anastomosed with the distal end of the mobilized segment end to side. The anastomosis should be made perpendicular to the long axis of the intestine and not opposite to the attachment of the mesentery

The mobilized jejunal segment is now drawn through a slit in the mesocolon and gastrocolic omentum and comes to lie in front of the stomach Now follows formation of a subcutaneous tunnel reaching from the upper end of the incision to a point well above the left clavicle. The undermining is performed with a large gastric crushing clamp in a way similar to that previously described Should the instrument not be long enough a small incision is made at the lateral side of the neck and the instrument reinserted from above to join the distal part of the tunnel The tunnel may however be made with a special instrument consisting of an iron rod tipped with a removable cone, as devised by Yudin

The large gastric crushing clamp used for undermining is now reinserted into the tunnel from below the tips being pushed to the end of the tunnel at the neck. The branches are opened slightly and raised until they can be felt at the blind end A straight needle with a long thread is introduced through the skin at that point. The tip of the needle is grasped by the gastric clamp and both are withdrawn This end of the thread is now tied to the pursestring suture of the blind end of the mobilized jejunum and under gentle pull at the thread the jejunum is drawn up into the tunnel The entrance to the tunnel should be separated widely with the fingers when the intestine with the mesentery is inserted The latter should be smoothed out and *pushed into the tunnel* care being taken not to twist the mesentery along the axis. The procedure is made easier if the intestine is gently pressed and massaged into the tunnel When the end of the intestine has reached the other end of the tunnel and the stump of the intestine can be palpated through the skin the end of the thread drawn out through the puncture wound is tied over a piece of gauze and the abdominal wound closed.

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Technic (Use of Transverse Colon for High Esophageal Anastomosis) Under endotracheal anesthesia the abdomen is opened and the lesser peritoneal cavity is entered through the gastro-colic omentum The proximal transverse colon is dissected free from liver and duodenum the distal end is mobilized to the splenic flexure The avascular lateral peritoneal attachments of the ascending colon and cecum are divided The colon is now divided at the splenic flexure and 10 cm (4 inches) above the ileo-colic junction the mesentery is transsected from either end of the segment to the middle colic vessels The ascending colon and that of the splenic flexure are anastomosed. The cervical esophagostomy is now dissected free. A tunnel is made in the anterior mediastinum behind the periosteum of the sternum from below and above. A long clamp is passed from the neck down to the mediastinal tunnel Stay sutures which have been applied to the proximal end of the isolated colonic segment are grasped and the colon is pulled through this tunnel into the neck. The anastomosis of the colon to the upper esophageal segment is now performed. If two teams are available the other team can anastomose the distal end of the colon to the stomach just proximal to the pylorus Just before completing the anterior suture line of the upper anastomosis a Levin tube should be passed through the nose down through the transplanted segment of the bowel into the stomach The neck muscles are then reapproximated over the anastomosis after a small drain has been inserted. The Levin tube should stay in place for about five days at which time oral feedings can be begun The gastrostomy tube should stay in place until the patient is eating normally

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and they can be used only for partial defects If the surface is cicatricial, all scar tissue, and in the case of a granulating surface, the entire granulating area, together with the cicatricial base, must be excised until the penis can be developed to full length A Foley catheter is then inserted and the penis covered with a thick split skin graft, unless the defect is deep and involves the corpora cavernosa If such is the case, flaps must be employed

In scrotal defect the use of free skin grafts to cover the testicles has been recently revised (Balakrishnan, Watson, Campbell) It may be worthwhile trying either as an initial or permanent coverage of the testicles although the coverage seems to be rather thin to provide adequate comfort The simplest way to provide initial coverage for the plexus and the testicles is to form a subcutaneous pocket on the median surface of the thighs (rarely on the abdomen) and burying the two structures beneath the skin (Seeman, Thierry, Krug, Owens, and others) This is usually done from a longitudinal incision or by undermining the skin from the former base of the scrotum near the groin It has been often and reliably stated (Moore, Harrenstein and others) that sterility ensues in a testicle that maintains a temperature equal to body heat instead of one degree less This, however, appears not to be the case as demonstrated by Brown and Fryer and others However, the patients, particularly the younger ones, may object to the deformity and develop a psychological handicap Hence, the testicles then should not remain buried permanently and a new scrotum should be constructed unless the patient accepts the deformity

The author has reconstructed a scrotum by means of two oblique pedicle flaps of the thighs beneath which the testicles were buried, the flaps were raised in stages and combined, thus deviating from the technic of Konig, who enveloped each testicle with the adherent flap and formed two separate units The author's method requires three or four stages over a period of four weeks. The functional and cosmetic result is very satisfactory A different principle was employed by Douglas He formed two large oblique, fan-shaped flaps with fairly broad pedicles left attached below in the upper median thigh regions, adjacent to the perineum, their axes paralleling the inguinal canals and their free ends being on the upper anterior thighs near the level of a horizontal line through the base of the penis They were rotated toward the midline and around their axes to receive the testicles and the cords, and they were sutured together Since the pedicles remain attached, the method is cosmetically inferior to the method outlined above It has, however, the distinct advantage of being a one-stage procedure

XVIII

THE GENITALIA IN MALE AND FEMALE

Defects

LOSS OF SKIN OF PENIS AND SCROTUM

Loss of skin of the male genitalia is due either to trauma or to infection. Such a defect may involve the penis the scrotum or both In traumatic cases in which the wound can be treated within the stage of contamination surgical restoration can be started almost immediately Before reconstruction can be undertaken in defects due to infection (necrosis of skin from infection following circumcision gangrene from erysipelas lymphogranuloma inguinale etc.) the infection must be combated first by local and general means and the granulations thoroughly prepared until they are healthy pinkish and flat The literature on this subject has been thoroughly discussed up to 1942 by Neal Owens up to 1950 by the author and more recently by Beverly Douglas

The missing skin of the penis can be replaced with skin flaps or skin grafts According to early reports on the restoration of penile skin surgeons have apparently preferred pedicle flaps rather than free grafts Lexer Brown Owens Byars Hamm and others however have demonstrated clearly that a thick split skin graft has an excellent chance of regeneration It remains pliable develops normal sensation and does not hinder erection The operation can be performed in one stage. In traumatic defects where the torn penile skin is still available it may unless it is dirty and ragged have a chance to heal in place and regenerate. However the prospect of success in replacement seems better if the skin remains attached even by a small bridge (Case 86 p 957) Flaps require multiple operations and when taken from thigh or abdomen are thick and may grow hair Scrotal skin flaps are pliable but the source is limited

from postoperative administration of antibiotics, bromides, and other sedatives are given to prevent erections

Stage 2. Nine days after the operation, the dressings are changed, sutures and catheter are removed, and the median pedicle of each bridge flap is severed under local anesthesia, one-third from each side, and a laboratory clamp is applied to the median third (Case 86, p 957) The penis is redressed with moist normal saline solution dressings Within the following few days, the median third is crushed with the clamp

Stage 3 Five days after the second operation, the same procedure as in Stage 2 is carried out at the lateral pedicles

Stage 4 One week after Stage 3, the flaps with the testicles closely attached are elevated, the nylon backing of the skin grafts is removed Should the flaps become cyanotic, they are returned to their former site for another week Otherwise, the operation can be completed by anastomosing the flaps in the following manner The lateral pedicles become the posterior raphe, and the median pedicles the anterior raphe, the lower oval openings of the flaps are sutured together, thus forming the bottom of the new scrotum The posterior rim of the upper oval opening is sutured posteriorly to the perineal region, the anterior rim is sutured to the pubic region

It is quite conceivable that an extensive traumatic avulsion of the skin of the male genitalia must, in some patients, result in profound psychological and endocrine disturbances, regardless of the surgical reconstruction Baxter and co-workers have recently stressed these consequences and described in detail the proper treatment

ABSENCE OF VAGINA

Absence of the vagina is a congenital abnormality usually associated with a rudimentary development of uterus and adnexa Yet, the external genitalia, as well as sex instinct and secondary sex characteristics, may be well developed Hence, construction of a vagina may be indicated to offer the patient the possibilities of normal sexual relationship and to prevent development of an inferiority complex

Another group of patients occasionally requiring construction of an artificial vagina are the so-called "pseudohermaphrodites" For the historical background and the details of the subject, I refer to the classic treatise of H H Young The author has presented the highlights, together with the latest research developments and his own experience, in a symposium (see also Case 89, p 964, Case 91, p 967).

Various methods of construction of a vagina have been developed, such as transplantation of a section of the intestine (Baldwin, Schubert)

Technic (Traumatic Avulsion of Skin of Penis and Scrotum) (Case 86 p 957) *Stage 1* After the entire area has been prepared in the usual way (soap and water) a thorough excision of ragged wound edges and débridement are performed.

The next step consists in supplying a protective covering for the exposed testicles hanging free on their spermatic cord and the preparation of oblique thigh flaps for the reconstruction of the scrotum. A double-pedicle oblique bridge flap is formed on the anteromedian surface of the thigh The upper incision is made just below (about 2.5 cm distally—1 inch) and parallel to the crease of the groin Each flap is 15 by 8 cm (6 by 3⅛ inches) Both flaps are elevated from the fascia lata. The testicle and the spermatic cord are now buried beneath the flap. The proximal and posterior part of the plexus rests upon the narrow strip of skin of the crease of the groin The remainer of the posterior part of the plexus and the testicle lie upon the raw surface of the thigh To prevent the testicle from growing to the donor area and also to prevent the flap from becoming reattached to its donor area the donor area should be skin-grafted at this stage by using a nylon backed thick split graft, cut with the dermatome from the median surface of the same thigh (p 38) The flap is now sutured to the wound edges of the donor area In the region of the spermatic cord it is sutured to the raw pubic area

The denuded penis is now covered with a thick split skin graft (Case 87 p 960) First an indwelling catheter is inserted and a traction suture placed through the glans A thick split skin graft is removed from a hairless region of the abdomen (the donor area should not be shaved preoperatively) The graft is wrapped around the penis Where the free edges of the long sides of the graft meet, a new raphe is formed. The raphe, however should not be straight but zigzag this shape is provided by making incisions on one side of the graft and leaving projections on the other side Thus a Z like plasty is performed to counteract contractions It is simpler however to make the suture line unbroken If this is preferred the scars should be placed on the dorsum of the penis in case light contracture should occur The graft is first sutured to the base of the penis. The sutures are left long The penis is held stretched by means of a holding suture through the glans and the graft is sutured longitudinally The distal part of the graft is then trimmed and sutured to the corona glandis These sutures are left long A heavily padded pressure dressing is applied which is held in place by tying the sutures over it, reinforced by strips of elastoplast A pressure dressing is applied upon the thighs by means of figures-of-8 around thighs and abdomen Aside

the cavity is controlled by insertion of hot moist sponges The size of the cavity is made to fit snugly over a previously prepared solid mold of plexiglas or other material Originally, the mold was cylindrical, now the upper end is made slightly larger than the remaining portion of the prosthesis in order to hold it in place more securely (Blocker) The average mold measures about 10 by 4 cm (4 by 1⅝ inches) (Case 88, p 962) The wider upper end has a rounded top, which lies toward the peritoneum The lower end, which lies against the urethra, has a troughlike depression, 1 cm (⅜ inch) in width and 3 cm (1³⁄₁₆ inch) in length This lower end also has a projecting disk attached with two openings for the reception of two rubber tubes to keep it firmly in place later on, as described in the following paragraph A thick split skin graft is now removed from a hairless region of thigh or abdomen (donor area not to be shaved) and—with its raw side out—is wrapped around the mold and fastened to itself with catgut sutures through its edges The moist sponges are removed from the newly formed cavity Should oozing persist, hot moist sponges are again inserted for a few minutes, they are then removed, the cavity is flushed with thrombol (see p 35), and mold and graft are correctly inserted into the cavity The freshened edges of the labia are sutured over the mold, to hold it firmly in place

After-Treatment The patient is kept postoperatively on a liquid diet She receives 5 cc of paregoric every two hours for six doses, antibiotics, and gantrisin On the fifth postoperative day, the diet is changed to soft foods, and 30 cc of mineral oil is administered every night Sutures and mold are removed on the tenth postoperative day, and the newly lined cavity is cleansed by irrigation The mold is then reinserted and held in place with two rubber tubes, which are threaded through the openings in the mold and fastened anteriorly and posteriorly to an abdominal belt The belt should be fitted preoperatively (see Case 88, p 962) The mold is removed every day for irrigation of the cavity Later, this can be easily done by the patient herself The mold should be worn continuously for three months to avoid contracture For the following three months, it is worn at night If the patient does not plan early marriage, dilatation should be carried out at regular intervals to avoid subsequent shrinkage

Deformities

By David M Davis, M D

HYPOSPADIAS

Hypospadias cases are classified as follows, according to the location of the external urethral meatus

pedicle flaps (Heppner Graves Frank and Geist) free skin-grafting (Abbé Esser) and gradual stretching of the rudimentary organ (Frank) The subject has been critically reviewed by Owens by Counsellor by Fletcher by McIndoe and more recently by Blocker and associates The most popular method is the use of an inlay skin graft that is the use of a thick split graft wrapped around a stent

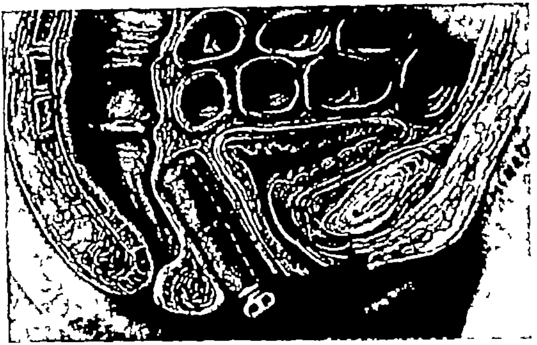

Fig 296: Reconstruction of vagina with inlay skin graft over a stent. Stent of plexiglas (10 × 4 cm) and skin graft inserted. For details of shape of stent see p 963.

Technic (Fig 296 Case 88 p 962) The patient s bowels should be prepared prior to surgery by evacuation the night before operation and by the administration of paregoric (5 cc.) at 8 P.M and 10 P M that evening and the same amount at 7 A M of the day of the operation The patient is kept on a liquid diet. It is also advisable to sterilize the bowel flora with sulfonamides and antibiotics (see pp 116 and 538) A retention (Foley) catheter is inserted in the urethra and the patient is placed in lithotomy position From a transverse incision midway between urethral meatus and anus the space between the urethra and the juncture of the labia majora is opened An assistant should now reach beneath the drapes and insert a finger into the rectum Along this guiding finger under blunt dissection a cavity is created between bladder and urethra on one side and the rectum on the other side care being taken not to perforate either organ not to enter the peritoneal cavity and not to make the cavity too roomy Few spurting bleeders are usually encountered at the level of the broad ligaments they should be ligated Oozing from

sary if free grafts are used, since they do not grow with the penis as do plastic reconstructions and pedicle flaps The writer believes that the years from five to eight, depending on the size of the child, are the most favorable period

The literature on the surgical treatment of hypospadias records a remarkable series of original ideas, patient and meticulous craftsmanship, amazing success, and, sad to say, many pompous and immodest ex cathedra statements and ill-natured disparagements of the other persons' methods While the surgical correction of hypospadias has always been regarded as very difficult, a study of the latest reports shows that excellent and practically identical results can be obtained with any of the presently recognized methods (Barcat, Browne, Byars, Carrai, Culp, Davis, Dodson, Douglas, Fogh-Anderson, Havens, Kiefer, Pariente, Schaefer, Smith, and Young) A great deal of the improvement in results must be ascribed to the antibiotic drugs and their conquest of postoperative infection

Methods· The following table will help to put the various methods in their proper relations

1 Straightening of penis with displacement of preputial skin to ventrum
   (*a*) Transverse incision closed longitudinally (Heinecke-Miculicz) (Fig 297, *1*, *2*)
   (*b*) Freeing and longitudinal splitting of prepuce (Edmonds) (Fig 297, *3*, *4*, *5*)
   (*c*) Freeing and buttonholing of prepuce (Nesbit, Ombrédanne) (Fig 297, *14*, *15*, *16*)
   (*d*) Freeing and oblique displacement of prepuce (Davis) (Fig 297, *11*, *12*, *13*)
2 Plastic construction of new urethral tube
   (*a*) Production of tube from ventral skin, without tunneling
      (1) Sutured tube (Thiersch-Duplay-Marion) (Fig 298, *1*, *2*, *3*, *4*)
      (2) Flat flap (Browne) (Fig 299, *1*, *2*, *3*, *4*, *5*, *6*)
      (3) Circular flap with pursestring suture (Ombrédanne)
   (*b*) Production of tube from ventral and scrotal skin (Bucknall)
   (*c*) Production of tube from dorsal preputial skin with tunneling (Mayo, Young, Davis) (Fig 300)
   (*d*) Production of tube by free graft with tunneling (Nové-Josserand, McIndoe, Havens) (Fig 301)
3 Covering of tube when not buried in tunnel
   (*a*) By flaps of penile skin
      (1) Straight edge flaps (Thiersch, Duplay, Marion, Blair) (Fig 298, *1*, *2*, *3*, *4*)
      (2) Staggered edges (Cecil) (Fig 298, *5*, *6*, *7*)
      (3) Mattress sutures plus dorsal counterincision (Browne) (Fig 299)

1 Glandular
2 Frenal
3 Penile
4 Penoscrotal
5 Scrotal (sometimes subdivided into anterior scrotal midscrotal and posterior scrotal)
6 Perineal

The glandular type requires no treatment the frenal type only for the sake of appearance since the urinary and sexual functions can be satisfactorily carried on in both All other types require plastic correction

Hypospadias may occur in the female the meatus being posterior to its usual location in the vulva or on the anterior wall of the vagina. Since incontinence is a rare complication no treatment is necessary unless it is present (van Bouwdijk)

The surgical procedures for the cure of hypospadias vary with the type and degree of malformation Before describing the different operations, it would be well to emphasize that adherence to a few principles is necessary for success. They are as follows

1 The penis must be thoroughly straightened, with the urethral orifice set back away from the tip if necessary

2 The urine must be clear and sterile.

3 The urine (according to most surgeons) should be diverted so that it does not come in contact with the tissues concerned in the plastic operation

4 The skin from which the new urethra is made must be hairless.

5 The new urethra must be of sufficient caliber at all points

6 The new urethra must be covered as deeply as possible and the sutures arranged so that one row does not lie directly over another

7 Erections should be avoided during convalescence

Before beginning plastic operations the operator must assure himself beyond all possible doubt that the patient is really a male. If the testes are undescended laparotomy is necessary for complete assurance Chromosome patterns are helpful Hormonal tests are not conclusive but when quantitative may be interesting and suggestive

The first question is usually that of the proper age for operation Practically all surgeons agree that the penis should be straightened or at least the straightening commenced as early as possible The plastic reconstruction of the urethra is delayed until the organs are larger Some believe it may be commenced at the age of four or five some prefer a year or two before the onset of puberty and a few wait until after puberty so that the penis may attain its full growth This last is particularly neces-

(*b*) By burying in scrotum (Cabot, Cecil) (Fig 302, *1-8*)

(*c*) By pedicle tube flap of scrotum (Wehrbein) (Fig 302, *9-14*)

Straightening of Penis The surgeons who earliest attempted surgical correction discovered at once that the down-curved penis must, in order to give a good result, be straightened before being supplied with the new urethra The straightening to be effective demands the absolute removal of all adhesions fibrous bands or other structures whatever their em

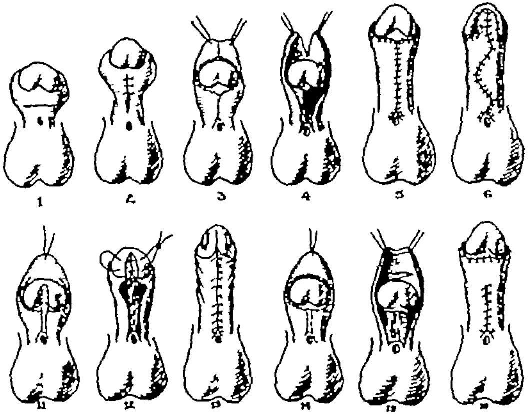

Fig. 297: Methods of straightening penis. (1 2) Heinecke-Mikulicz method. (3 4, 5) Edmonds methods. Adhesions shown in 4 must be thoroughly removed. (6) Byars modification. The glans is deeply incised, and the cleft so made is lined with preputial skin. (11 12, 13) Davis method. Cleft in glans is denuded, the two halves of the glans brought together by mattress suture (14 15 16) Nesbit's method. The preputial skin is completely freed from the penis, a dorsal incision made as in 3 the glans thrust through this opening, bringing much of the prepuce onto the ventral surface The original incision is closed.

bryological origin may be which hold the corpora cavernosa in the curved position This sometimes involves the removal of the ventral portion of the septum between the corpora cavernosa but must nevertheless be prosecuted most radically until perfect straightening is achieved When this is accomplished the lengthening of the ventral surface requires more skin to cover it and there are various ways of doing this

the previous one, so that any failure of primary union will surely produce a fistula The successful covering of the tube by skin without fistula formation has, for these reasons, its difficulties, and we shall presently consider the various procedures which have been suggested to make it more certain It is also difficult to bring the external meatus of the new urethra to its proper position at the tip of the glans Byars' method of splitting the glans (see above) is designed to overcome this objection

Flat Flap Denis Browne omits the suturing of the ventral rectangular flap into a tube, and does not even free the lateral edges of the flap from the underlying tissues He does free the lateral flaps of the penile skin very extensively, and in addition makes a median longitudinal counter-

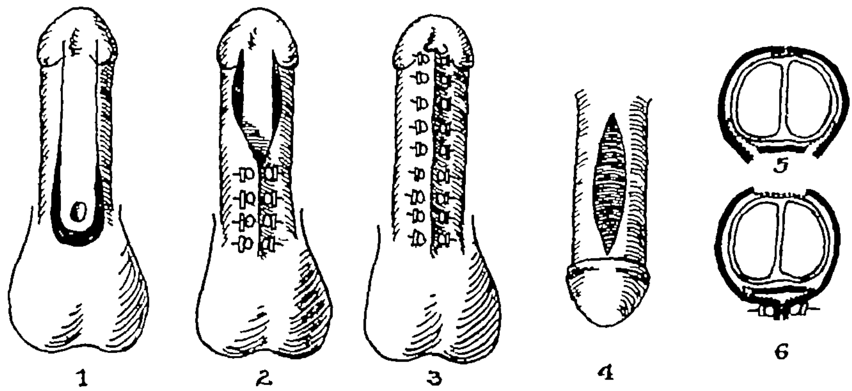

Fig 299 Denis Browne method of constructing new urethra. (1) The rectangular strip outlined (2) It is not freed, but the lateral skin edges are deeply undermined and drawn over the strip by mattress sutures (3) Operation finished (4) Dorsal counterincision to mobilize lateral skin edges (5, 6) Cross sections Note that the rectangular strip is not freed up from the underlying tissue at all

incision on the dorsum so that the skin edges can be drawn easily over the flat flap and deeply mattressed with nonabsorbable sutures passing through beads held in place by metal clips on the sutures (Fig 299, *1, 2, 3, 4, 5, 6*) The object is to produce a wide approximation of denuded subcutaneous tissue over the flat flap which, in the experience of Browne, tends to produce primary healing without fistulas The buried flat flap, by proliferation of its edges, forms itself into a tube According to the experiments of Nesbit, the flat flap should be cut of a width equivalent or almost equivalent to the circumference desired for the completed urethra, Browne feels that it need not be quite so wide

Circular Flap with Pursestring Suture In an effort to create a new urethra without suture lines and to avoid any necessity for diverting the urinary flow, Ombrédanne suggested making a circular flap with the hypospadic meatus at its center, the radius of the circle being equal to the distance from the meatus to the end of the penis The edges of this cir-

a nearly circular outline and so make it more suitable for the tunneling procedure to be carried out later Young and Benjamin recommend the same procedure as a preliminary to their free-graft method of reconstructing the urethra (Fig 297 *11, 12, 13*)

The results of straightening operations must be appraised carefully and if the straightening is not perfect the procedure must be repeated as many times as necessary to make it so

Since the preputial skin is so important in the plastic correction of hypospadias all physicians should be aware that a hypospadias patient must *never* be circumcised, and rabbis should be urged to make their ritual circumcisions in such cases as vestigial as possible

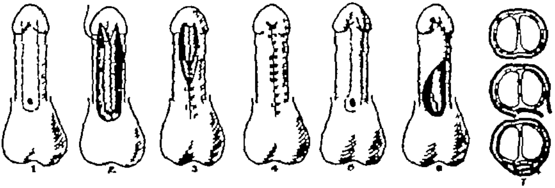

Fig. 298 Thiersch-Duplay method of constructing new urethra. (1) Incision (2) strip of skin formed into a tube (3) subcutaneous tissue closed over new tube (4) skin closed. (5 6, 7) Cecil modification. (5) The strip is cut to one side of the midline (6) In closing, the skin incision does not lie over the suture line in the tube (7) cross sections. Note that only one side of the rectangular strip is freed up from the underlying tissue.

Plastic Construction of Urethral Tube. *Sutured Tube* The oldest and simplest method of constructing a urethral tube is to raise the edges of a rectangular skin flap on the ventrum of the penis and suture it into a skin lined tube as shown in Fig 298 *1, 2, 3 4* This method is usually known by the coupled names of Thiersch and Duplay but it has been used and modified by many others and in this country the name of Blair is particularly associated with it Marion modified it by using one set of sutures to produce the tube and to mattress the skin edges. The sketches in Fig 298 show the simplest closure. Subcutaneous tissues are brought together over the tube by interrupted sutures of very fine catgut and the skin edges are closed by fine nonabsorbable sutures which may be plain or mattress and may or may not be tied over small rubber tubes beads or other devices to prevent them from cutting into the skin It will be noted however in Fig 298 *3* that no matter how carefully they are placed, the sutures all lie in the same plane each line superimposed on

served human urethra from fresh cadavers (Bourque), and large veins (Tuffier)

Covering of Tube. *Flaps of Penile Skin* The simplest method of covering the newly made urethra when it is not buried in a tunnel is to suture over it the straight-edged lateral flaps of penile skin (Fig 298, *3, 4*) Plain or mattress sutures may be used, as shown in Fig 298, *4, 6,* and the flaps may be freed by a counterincision on the dorsum of the penis, as shown in Fig 299, *4*

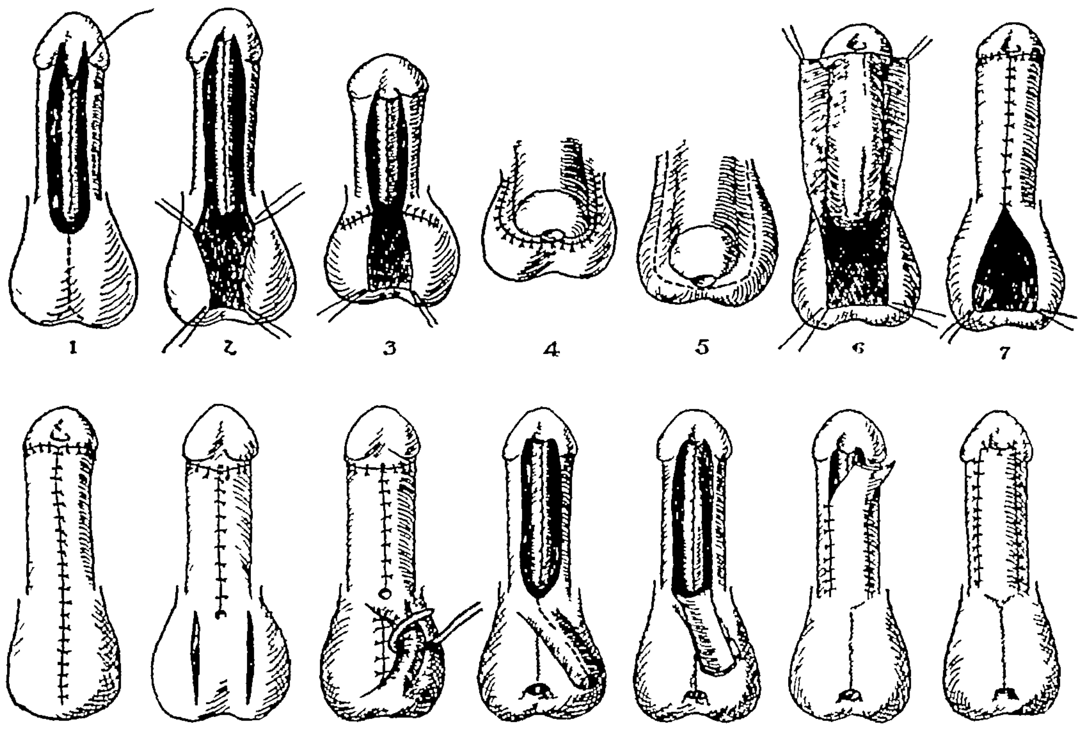

Fig 302 Methods of covering new urethra (1 to 8, inclusive) Cecil-Cabot method (1) Incision extended on scrotum (2) Edges undermined, (3, 4) Penis sutured to scrotum, (5) *After healing, incision made providing flaps of scrotal skin sufficient to cover ventrum* of penis as shown in 6 (7 and 8) Closure of penis and scrotum (*9* to *14* inclusive) Wehrbein method (9, 10) Double pedicle tube flap raised on scrotum (11, 12) After healing, lower pedicle is divided, tube incised on ventral surface, unrolled into a flat flap and used *to cover Thiersch-Duplay plastic as shown in 13 and 14*

Separation of Suture Lines Cecil proposed that the rectangular flap be cut mostly to one side of the midline, and that only the edge farther from the midline be freed up This edge is then drawn over across the midline and sutured to the opposite, unfreed edge. Thus, when the lateral penile flaps are drawn over the new urethral tube and sutured together, the skin suture line will not lie directly over the urethral suture line, but will be separated from it by a considerable distance (Fig 298, *5, 6, 7*)

cular flap are gathered together with a pursestring suture and the new urethra and the raw area left by the raising of the circular flap are then covered by the freed and buttonholed prepuce which is drawn over the glans and tacked down on the ventral surface of the penis This method is entirely unsuitable for cases in which the hypospadic meatus is farther back than the midpenis and even where applicable it produces a very wide redundant funnel shaped urethra. The present author believes that the Ombrédanne operation is now entirely outmoded and superseded by other and better operations.

Formation of Tube from Ventral and Scrotal Skin Bucknall described a method in which the new urethra is formed from two narrow strips of skin one from the ventrum of the penis the other from the scrotum. The lateral penile flaps and the lateral scrotal flaps are then sutured together, temporarily burying the new urethra between penis and scrotum This means that the new urethra has two longitudinal suture lines instead of one, and that its floor being of scrotal skin will give forth an abundant growth of hair For these reasons the Cecil modification shown in Fig 302 *1 2 3 4 5 6 7 8*, is now usually preferred Variations of this method for penile hypospadias have been described by Mathieu and Leveuf

Tube Made from Dorsal Preputial Skin with Tunneling Mayo and Young described operations in which a tube made from preputial skin and remaining attached by a pedicle at one of its ends was drawn through a subcutaneous tunnel in the glans The object of this was to do away with the possibility of fistula formation However thinking to have the pedicle as near the tip of the penis as possible they left the tube flap attached by its distal end and it proved that the blood supply so provided was inadequate For this reason the tube flap often sloughed and the method was not satisfactory Davis modified the method by leaving the tube flap attached at its proximal end which preserved the dorsal artery of the penis and prevented sloughing The tunnelized penis was then bent over backward to receive the tube flap The tunnel must be large enough to admit the tube flap perfectly freely Experience showed that this method was practical and that erections did not interfere with its success. It further demonstrated that tube flaps made in this manner could be cut the entire length of the dorsum of the penis back as far as the point where pubic hair follicles began to appear These long tubes are perfectly viable and permit the penile tunnel to be made as long as the tube flap often reaching all the way to a meatus at the penoscrotal junction Anastomosis with the preexisting urethra can be made at the time of the original operation or later The pedicle of the tube flap is divided about three weeks after its formation by which time the tube

tent the skin, and then snips off with fine scissors a bit of skin containing the follicle

In perineal hypospadias, a vagina, shorter or longer, is often present If short, it is easily removed (Fig 304) If longer, its removal may be more complicated, since it may run very close to the anterior wall of the

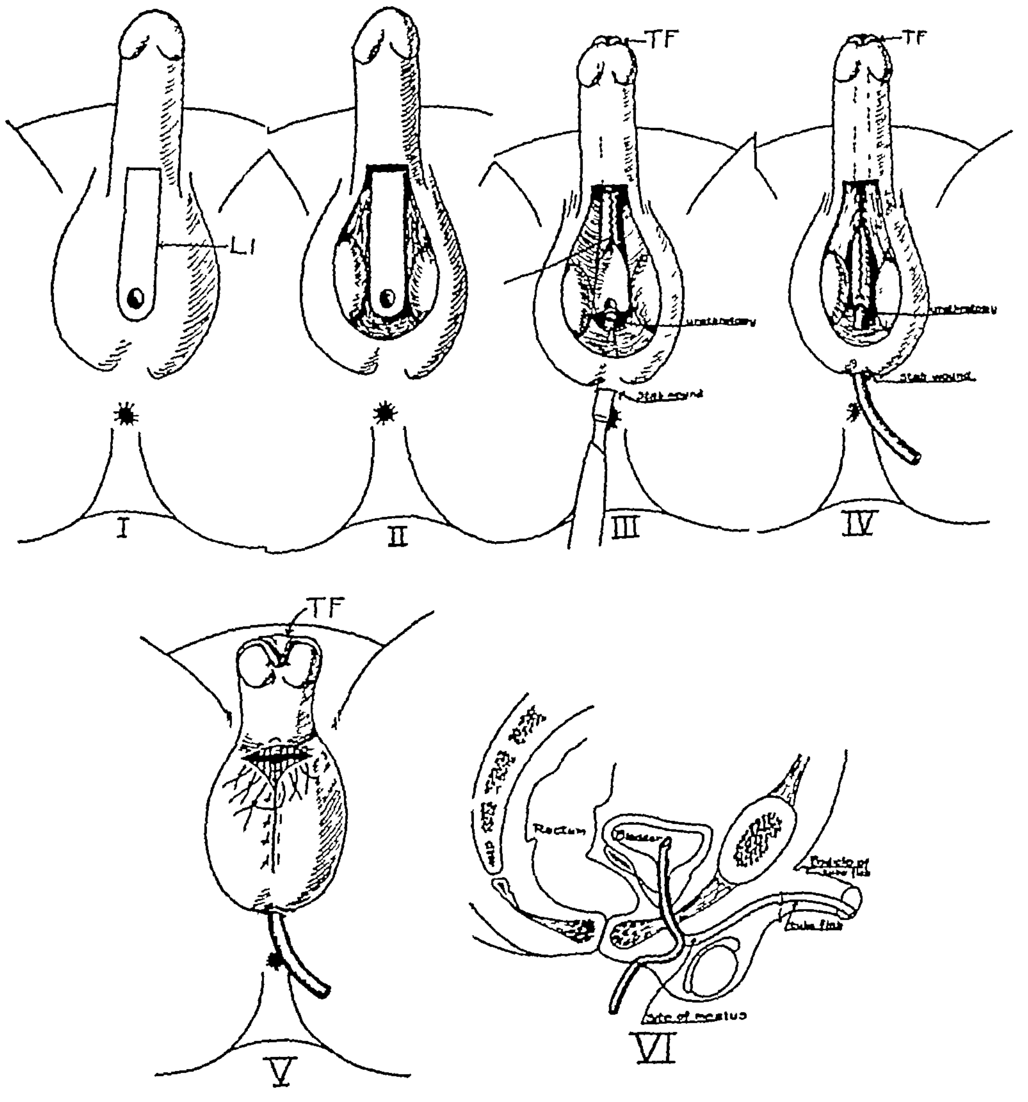

Fig 303· Method of operating on mid-scrotal hypospadias (Davis) (I) Median rectangular flap cut as usual for Thiersch-Duplay type of tube formation, ending distally at a point which can be reached by a Davis type pedicle tube flap brought through a penile tunnel (II) Edges of flap raised, edges of incision deeply undermined (III) Davis type pedicle tube flap formed, brought through penile tunnel and anastomosed to Thiersch-Duplay type of tube formation in scrotal area Stab wound made from perineum through scrotal tissues, urethrostomy opening made proximal to pre-existing meatus (IV) Urethral tube completed, drainage catheter (Foley) inserted to bladder through urethrostomy, scrotal tissues drawn together over new urethra to bury it as deeply as possible (V) Scrotal incision closed In distal part scrotum and penis are sutured together according to the Cecil-Cabot principle (Fig 302), the resulting web to be divided later (VI) Diagrammatic sagittal section of conditions after division of the pedicle of the tube-flap three weeks after its formation

Covering Tube by Burying in Scrotum Other surgeons have gone to even greater lengths to provide abundant cover for the new urethral tube A method ascribed to Cecil and also used by Cabot is to make a midline incision in the anterior surface of the scrotum continuous with the incisions outlining the rectangular flap of skin from which the new urethra is to be constructed (Fig 302 *1, 2*) The edges of this incision are deeply undermined and, at the time of closure, they are sutured to the corresponding lateral penile skin flaps (Fig 302 *3, 4*) so that the urethral tube is deeply buried between penis and scrotum (Fig 302 *4, 5*) Some weeks later after healing is complete and the urethra intact, penis and scrotum are cut apart, leaving some scrotal skin sufficient to cover its ventrum attached to the penis on each side (Fig 302 *5, 6*) These flaps are then sutured together over the urethra and the scrotal incision is closed longitudinally (Fig 302 *7, 8*)

Covering of Tube by Pedicle Tube Flap of Scrotum Another ingenious method was described by Wehrbein At least several weeks before the construction of the new urethra two parallel longitudinal incisions are made in the anterior surface of the scrotum and extending up to the level of the base of the penis (Fig 302 *9*) The skin between these incisions is undermined and sutured into a tubular structure attached at both ends and with the skin outside The scrotal halves are sutured together beneath it (Fig 302 *10*) After healing is complete, the new urethral tube is constructed Before closure of the penile incision the tubular structure is cut away from its lower pedicle incised along its anterior aspect and unrolled into a rectangular skin flap (Fig 302 *11, 12*) This flap is then turned up applied over the new urethra and sutured to the lateral penile skin edges (Fig 302 *13, 14*) This flap being of scrotal skin will bear hairs but this is of little importance since it involves only the outer surface of the penis and not the urethra.

Special Considerations The above-described methods may be applied whenever the urethral meatus is at any point on the penis including the penoscrotal junction If the orifice lies farther back in the midscrotal posterior scrotal or perineal positions the Thiersch Duplay principle may be used with no fear of fistula formation since in this region it is easy to bury the new urethra very deeply

If as often happens a midline strip of hairless skin is present (Fig 303) this procedure is comparatively simple but if hair follicles are present careful and thorough depilation must be carried out before fashioning the new urethra Individual destruction of hair follicles by electrocoagulation is more satisfactory than x ray Havens pulls on the hair to

number of individual subcutaneous sutures The edges of the skin incision are then closed by mattress sutures of nonabsorbable material. Byars modifies this procedure by using fine nonabsorbable material for the pursestring suture, and bringing the ends of the suture out through the skin at a considerable distance lateral to the skin incision, where they are tied over a bit of rubber tissue or tubing This keeps the fistulous tract away from directly beneath the skin incision, and decreases the chance of

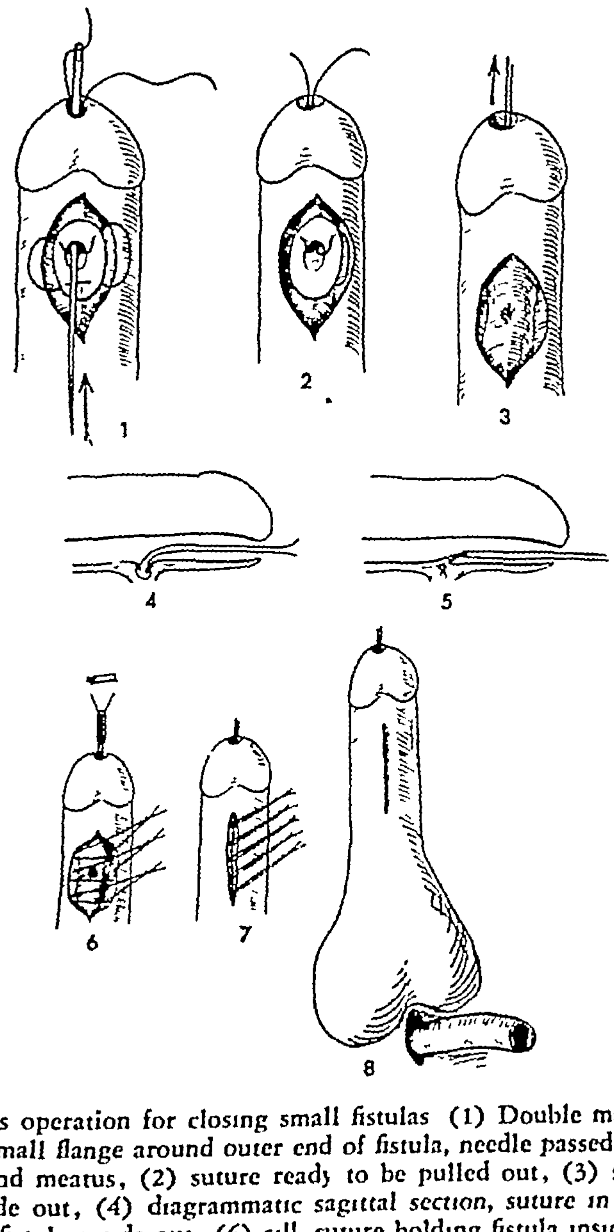

Fig 305 Davis operation for closing small fistulas (1) Double mattress silk suture taken in edge of small flange around outer end of fistula, needle passed butt first and out through urethra and meatus, (2) suture ready to be pulled out, (3) suture pulled and fistula turned inside out, (4) diagrammatic sagittal section, suture in place, (5) same, suture pulled and fistula inside out, (6) silk suture holding fistula inside out fastened to abdomen by rubber band, pursestring about site of fistula, subcutaneous sutures placed, (7) subcuticular sutures placed Mattress sutures may be used, with protection from cutting (rubber tubes or beads), or, if covering tissue is inadequate, penis may be sutured down to scrotum according to Cecil-Cabot principle (see Fig 302, 1-8) (8) Incision closed by subcuticular sutures, catheter in perineal urethrostomy.

rectum A number of authors attest that such a vagina may be left in place without ill effects (Cecil) In all such cases it is essential to be absolutely certain before proceeding with urethral construction that the real sex of the patient is male.

Almost all authors recommend diversion of the urine during the healing stage of the plastic urethral construction In cases of perineal

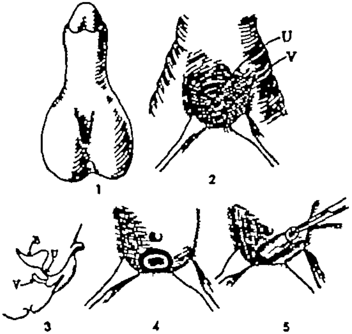

Fig 501: Case of perineal hypospadias. (1) External appearance after straightening of penis. (2) Edges of skin lappet covering urogenital sinus retracted showing vagina, V and urethra U Dotted line is incision circumscribing vagina (3) Diagrammatic sagittal section. (4, 5) Dissection and complete removal of vagina.

hypospadias it may be necessary to perform cystostomy If so the drain should be kept in place until the plastic procedures are completed. In all other cases perineal urethrostomy will suffice. A Foley catheter should be used as a drain and may be removed as soon as the operative incision is healed even if further operation is to be carried out, since the reestablishment of a perineal urethrostomy is very easy In posterior scrotal hypospadias the drainage tube may be brought out from the operative incision through a stab wound in the perineum (Fig 503) Douglas trains his patients to void slowly to avoid excessive pressure in the new urethra and finds that this often makes urinary diversion unnecessary

If urethral fistula does occur its closure may be somewhat difficult The usual procedure is to cut around the fistula free it down to the urethra and amputate it. The tissues are then closed over the opening in the urethra by a pursestring suture of fine catgut reinforced by a

In the surgery of hypospadias, one is dealing with very delicate and highly elastic integument It is therefore very easy to distort the flaps in the process of cutting them, and the greatest care must be exercised to avoid this Exactly equal tension must be exerted upon the skin in all directions during the entire process of cutting the flap, otherwise its edges will not be parallel The author has found the curved sharp-pointed scalpel blades of great value in this connection For handling the delicate tissues, particularly in children, the small forceps and scissors used in ophthalmic surgery are ideal

EPISPADIAS

In epispadias, the defect in the urethra may involve only the glandular part or it may extend back any distance The entire penile urethra may be open dorsally without any incontinence, but if the anomaly involves the deep urethra, there may be great widening of the channel and complete incontinence In some cases, it may even be possible to insert a finger into the bladder Naturally, if such conditions are present, the plastic operation on the penis must be supplemented by further procedures on the deep urethra and vesical orifice to provide urinary control

The penile part of the operation is the same in principle regardless of the extent of the deformity It is the writer's opinion that only one method needs to be described, namely, Young's modification of Cantwell's procedure It is superior to other methods in that it preserves the blood supply of all parts, it brings the urethra to its proper ventral position, and it reconstructs the broad, spadelike penis to an essentially normal form The use of grafts and flaps to cover the new urethra only serves to preserve or increase the deformity of the penis

Technic (Young's Modification of Cantwell's Procedure) (Fig 307) The urethra is constructed according to the same principles as those used in the Thiersch-Duplay procedure for hypospadias When the incision is made, outlining the strip from which the new urethra is to be built, one limb of this incision is extended deeply down between the corpora cavernosa to the ventral part of the penis, as shown in the small cross-sections in Fig 307 This leaves the new urethra firmly attached to one corpus for its blood supply, and mobilizes the corpora so that they can be rotated The urethra is formed by suture in the usual manner, using continuous or interrupted sutures of the finest plain catgut The corpus to which the urethra remains attached is then rotated until the urethra lies under the ventral skin of the penis in its normal position, and is held in this position by numerous sutures of fine chromicized catgut penetrating the tunica albuginea and holding the two corpora closely together.

recurrence of the fistula. Davis does not amputate the fistula after carefully freeing it, but takes a mattress suture in the outer edges of the fistula brings the ends of the suture out through the urethra and by traction on these ends turns the fistula inside out into the lumen of the urethra. This inversion of the fistula is maintained by fastening the ends of the inverting suture to the abdominal wall by means of another suture and a light elastic band so that slight elastic traction is exerted continuously (Fig 305) The subcutaneous tissues and the skin incision are

Fig. 306 End-result of surgical treatment in penoscrotal hypospadias.

then closed over the site of the fistula described above Diversion of the urine usually by perineal urethrostomy is most important and is advised by practically all surgeons

The author believes that in hypospadias surgery the administration of antibiotic drugs immediately before operation and during the post operative period is of the utmost value since a slight infection can impair an otherwise perfect result Since coccal infections are the most damaging one should give not only a wide-spectrum antibiotic, but also one particularly active against staphylococci and streptococci If the patient is sensitive to penicillin erythromycin or novobiocin is satisfactory

the middle panel of Fig 308 at X One should try to make the reconstructed urethra, in an adult, about the size of a No 12 French catheter The closure of the urethra is accomplished by interrupted suture of fine chromicized catgut At the site of the vesical orifice, every effort must be made to bring up as much muscle tissue as possible from the muscular wall of the bladder, and suture it over the new vesical orifice If the urethra is too large, incontinence will continue, if it is too small, it can easily be dilated

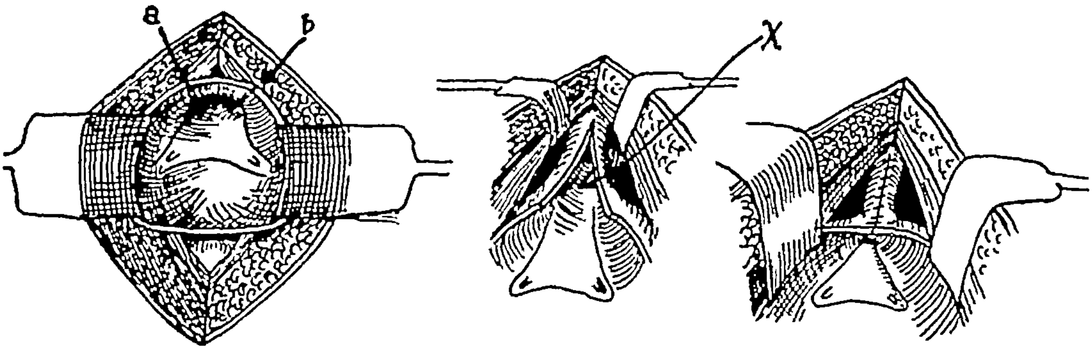

Fig 308 Young operation for epispadias with incontinence From left to right (1) bladder opened (2) Triangular area excised at X to reduce vesical orifice to normal size. (3) Urethra reconstructed by sutures Other mattress sutures are used to draw rudiments of internal sphincter over new vesical orifice *a, b* Tissue to be removed X Site of new vesical orifice

The results of operations for epispadias are usually good, even to restoration of urinary control Diversion of the urine is necessary here, as in surgery for hypospadias Perineal urethrotomy can be used only in the mild forms of glandular epispadias, in all other cases, suprapubic cystostomy is necessary The methods described here are useful for restoration of the penis in cases of extrophy of the bladder The urethra should be carefully reconstructed back as far as the verumontanum, even when the ureters are to be transplanted into the rectum and the bladder excised, in order to make sexual relations possible and provide egress for the semen.

PHIMOSIS

The commonest congenital malformation of the penis is phimosis This name is properly applied only to those cases in which the preputial orifice is so small that retraction of the prepuce is difficult or impossible Phimosis is treated by circumcision or posthectomy, which consists in the removal of a part of the prepuce, including the narrow preputial orifice It must be remembered that this same operation is often performed for redundant or elongated prepuce, even when no real phimosis is present

This apposition may be further insured by through-and-through stay sutures of nonabsorbable material if desired. The two halves of the glans are then sutured together over the urethra and here one or two nonabsorbable mattress stay sutures are desirable. They should be tied over small soft rubber tubing not as shown in Fig 307.

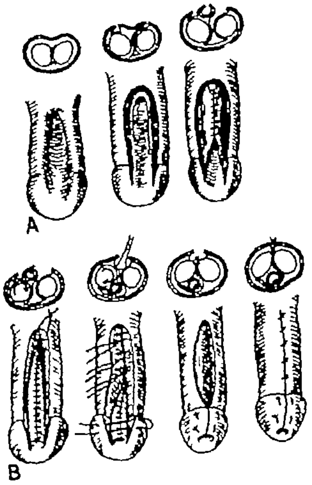

Fig 307 A: Young-Cantwell operation for epispadias. U-shaped incision, formation of new urethra by suture. Cross-sections show how incision is extended down between corpora cavernosa almost to ventral surface. B Urethra completed, corpora cavernosa drawn together over it. Arrows in cross-sections show how one corpus cavernosum is rotated to bring new urethra to ventral surface of penis.

If the epispadias is complicated by dilatation of the deep urethra and incontinence a corrective operation such as that seen in Fig 308 should be performed. When the bladder is opened suprapubically the greatly widened vesical orifice is seen and a segment *a-b* marked for removal. One should aim to leave enough behind to make an orifice a little smaller than normal. The cutting of this wedge-shaped segment should be continued down the urethra until well away from the bladder as shown in

Technic: Circumcision is performed as indicated in Fig 309 In newborn babies, no anesthesia is used With older children, general anesthesia is usually necessary With adults (or children with unusual composure), local anesthesia is the choice Procaine, 0 5 per cent, is the agent most often used The injections are usually made near the base of the penis, and through four wheals, one dorsal, one ventral, and two lateral Special attention is paid to the dorsal cord of lymphatics and nerves The tunica albuginea of the penile corpora should not be penetrated After the anesthetic is injected, a tourniquet may be applied if desired For

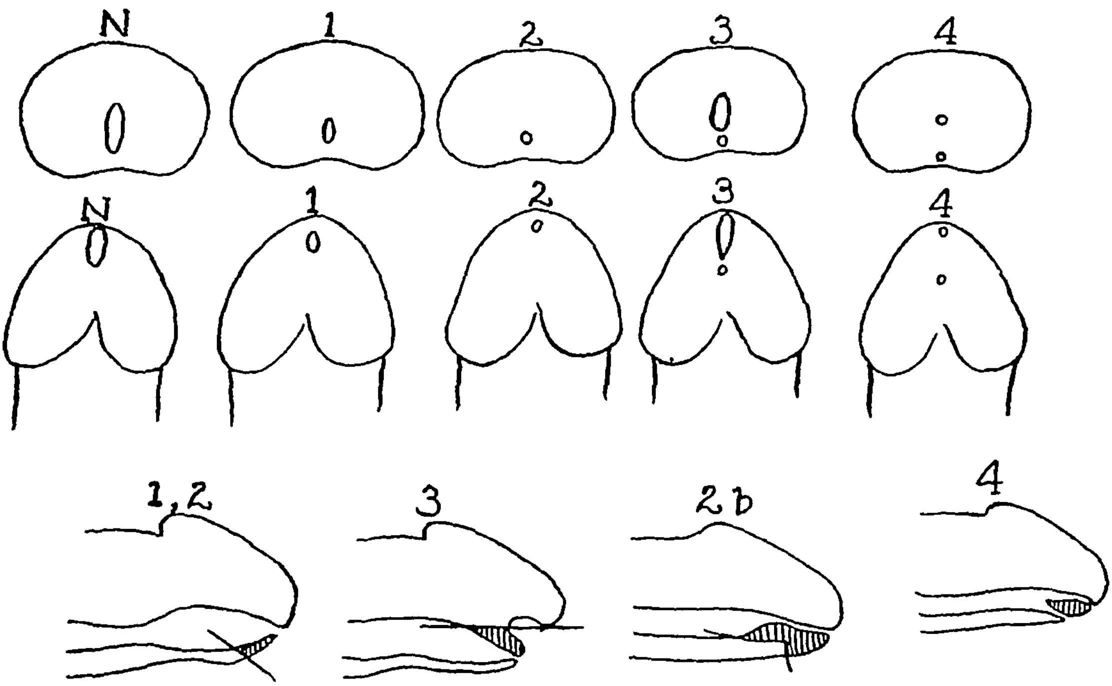

Fig 310 Meatotomy N Normal *1* · Small meatus *2* Pin-point meatus *3* Pin-point meatus with blind meatal gutter *4* Double pin-point meatus In sagittal sections, shaded areas represent tissues to be incised *2b* Procedure when meatal stricture extends some distance down urethra

this a No 10 or No 12 rubber catheter is satisfactory It is important to note that the foregoing injections will not anesthetize the inner leaf of the prepuce Further subcutaneous injections must therefore be made around the coronary sulcus, after the prepuce is retracted (Fig 309). At this time, any adhesions to the glans should be completely separated Firm wiping with gauze is usually sufficient, but if it is not, a fine-pointed hemostat may be thrust in along the coronary sulcus, and the blades spread If retraction of the prepuce is difficult or impossible, a dorsal slit is made with scissors The slit should extend all the way from the circular line of incision about the shaft to the line of incision in the

Circumcision is a simple innocuous procedure but it can be and only too often is done incorrectly The necessities for a proper circumcision are as follows

1 The lines of incision must be traced beforehand so that they will be even and symmetrical and that neither too much nor too little will be cut away (Fig 309)

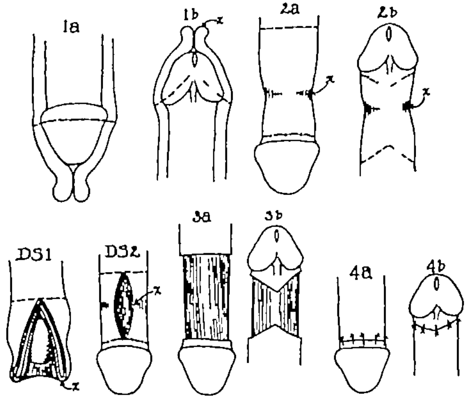

Fig. 309 Circumcision (posthectomy) *1a* Line of incision on dorsum of penis. *1b* Line of incision on ventrum of penis. *x* Edge of contracted preputial orifice. *2a:* Prepuce drawn back. Preputial orifice *x* now surrounds and constricts shaft. Second incision now made close to glans dorsally *2b:* Ventrally this incision is made V-shaped to avoid frenum. *DS1* If preputial orifice is too small to permit retraction both layers of prepuce are incised in midline dorsally to level of coronary sulcus (dorsal slit) *DS2:* Prepuce is then retracted and second incision around penis made as in *2a* and *2b* *3a* *3b* All of skin between two incisions around penis is removed, bleeding points ligated or coagulated. *4a* *4b:* Skin edges drawn together and closed by interrupted sutures, leaving glans uncovered.

2 Phimosis is often complicated by an adherent prepuce All adhesions between prepuce and glans must be completely separated

3 Phimosis is often complicated by congenital stenosis of the meatus (Fig 310) This must be detected and if present treated by meatotomy

4 The skin must be left longer in the frenal region to avoid tension on the frenum during erection and intercourse and yet not too long

5 Hemostasis must be good.

6 The skin edges must be accurately approximated

they are joined (Fig 310, *4*) If the stenosis is at the termination of a glandular hypospadic urethra, so that it is desirable not to extend it farther in the proximal direction, it can be widened without displacing it farther backward by making a small incision laterally on each side of the meatus (lateral meatotomy) Sometimes the stenosis extends some distance down the urethra, as shown in Fig 310, *2b* If so, the stricture must be divided throughout its entire length A blunt or probe-pointed bistoury is desirable for this After meatotomy, a single, plain catgut suture may be placed in the angle of the incision to prevent reclosure

Bleeding from the cut edges may be arrested by pressure, a silver nitrate stick, or electrocoagulation The incision itself may be made with the electric cutting current, which obviates bleeding For meatotomy, sufficient anesthesia is usually obtained by placing in the meatus for a few minutes a cotton swab soaked in cocoaine, 10 per cent, tetracaine (pontocaine), 2 per cent, or any other good local anesthetic If more is required, a few drops of procaine, 1 per cent, can be injected about the meatus with a fine hypodermic needle

ACCESSORY URETHRA

The variety of forms of accessory urethra is almost endless The treatment, if treatment is necessary, can only be complete excision If the accessory urethra reaches the bladder, the procedure is more complicated, and must be planned according to the conditions present

OCCLUSION OF MEATUS

This condition is rare Often the occlusion is membranous, and needs merely to be slit open In other cases, the whole distal part of the urethra is obliterated, so that cystotomy is necessary to find its extremity With these more advanced forms, umbilical fistula may be present and give exit to the urine

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coronary sulcus The skin included within these lines of incision is then dissected away from the underlying tissues There will usually be several bleeding arteries especially in the midline dorsally and in the frenum ventrally They are seized with fine pointed clamps and may be tied with fine plain catgut or the clamps may be touched with a coagulating electrode The skin edges are then drawn together with interrupted sutures Silk may be used, but must be removed later The usual practice is to use No 00 or No 000 plain catgut, which does not require removal Eight sutures usually suffice but more may be put in if the line of suture gapes. At this time, the meatus should be carefully examined and if any stenosis is present meatotomy should be carried out, as described in Meatal Stenosis see below

Innumerable modifications of the operation of circumcision have been proposed and it would be impossible here to describe them all If the principles outlined in the foregoing are adhered to good results are assured An ingenious device called the Gomco clamp has proved useful It clamps the outer and inner layers of skin so tightly together that after the excision is completed, they do not separate and the sutures can be placed without any bleeding

After-Treatment Since it is difficult to keep a dressing in place over a circumcision it is wise to leave the ends of the skin sutures long, and tie them over a strip or bundle of petrolatum gauze about 1 cm (3/8 inch) in diameter This holds the gauze in place. Dry gauze can be placed over the petrolatum gauze and held in place with strips of adhesive plaster running spirally about the penis and then along the groins This is not necessary in infants The end of the glans is left uncovered to permit voiding The long ends of the sutures and the petrolatum gauze are usually removed on the fourth day Little or no further attention is required Ordinarily the patient is not kept from his usual occupation

MEATAL STENOSIS

This condition is not quite so common as phimosis, but is all too frequently neglected A pinpoint meatus can cause serious trouble particularly by keeping up infection in the urethra and higher in the urinary tract. The usual types are shown in Fig 310 The type shown in Fig 310 *3*, is particularly deceptive since the blind pouch is often taken for a normal urethral meatus

Technic· The types shown in Fig *310 1, 2,* are the commonest. The diagram shows how the membrane partly covering the meatus is slit ventrally In the type shown in Fig 310 *3*, the septum separating the urethra from the blind pouch is divided. If two small orifices are present,

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XIX

DEFECTS OF SPHINCTER ANI MUSCLE

ANAL incontinence is due to injury or absence of the musculus sphincter ani. Various procedures have been offered for repair or replacement of the sphincter Their choice depends on whether the muscle is totally absent or destroyed or whether larger parts of the muscle are intact The group of patients in whom the muscle is absent or totally destroyed is small In such cases, restoration of control of the anal outlet can be achieved only by transfer of voluntary-muscle action Far more numerous are the patients in whom the sphincter muscle is only partly destroyed Direct suture of the divided muscle may be attempted if the rent is small, in larger defects, however, where up to half of the sphincter muscle is missing, a two-stage plastic procedure—as devised by Blaisdell—has been found successful.

In determining the extent of the defect, the anatomical appearance is of greater value than the clinical picture Wherever the muscle is destroyed, the overlying skin tends to be smooth and depressed, while the skin over intact muscle is folded

Total Defect of Sphincter Muscle

In total defects of the sphincter, various procedures, consisting in transfer of voluntary-muscle action, have been offered. Shoemaker's transfer of gluteal-muscle flaps has been modified in various ways Stone, having tried most of them without much success, developed a method which was based upon an original idea of the Russian orthopedic surgeon, R R Wreden Stone and others, who have had considerable experi-

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Technic (Wreden-Stone). *Preoperative Preparation* The patient is admitted to the hospital a few days before the operation and prepared with a low-residue diet, 30 cc of castor oil is administered On the last two preoperative days, the colon is cleansed by enema. The night before the operation, 5 cc. of paregoric is administered at 8 and 10 P.M. and the same amount again at 7 A M on the day of the operation Sulfonamides, terramycin, or a combination of the newer antibiotics are added (p 116). (When the bowels are sterilized and the bacteria which produce vitamin K have been killed, it may be necessary to supplement vitamin K)

Procedure (Figs 311–313) Two fascia-lata strips are removed from the patient's thigh with the fascia-stripper (see p 45) They should be 15 cm (5⅞ inches) long and 0.5 cm. (³⁄₁₆ inch) wide They are

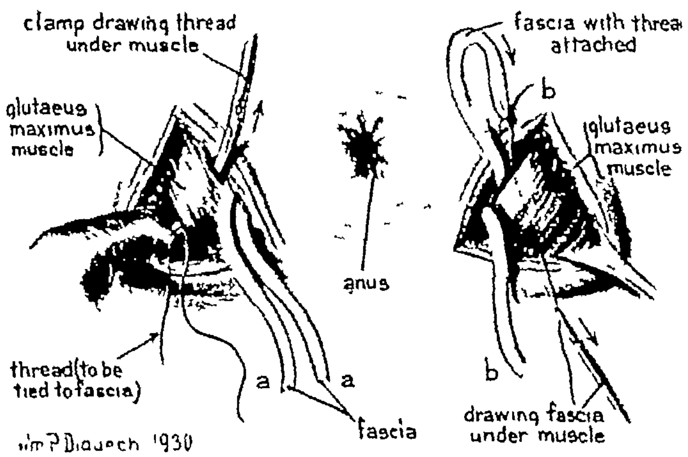


Fig 312 One free end of each fascial strip is passed around a substantial bundle of gluteus muscle (H B Stone Arch. Surg)

wrapped in moist gauze. The small incisions are closed with silk sutures and the patient placed in the lithotomy position

A small incision is made on the left and right sides, along a line joining the tip of the coccyx to the tuberosity of the ischium, and about 2 cm (¾ inch) posterior to the anal margin These wounds are deepened bluntly into the subcutaneous fat. By blunt dissection, a curved Kelly clamp is pushed from one incision to the other, in front of the rectum, in the subcutaneous fat, care being taken to avoid injury to the rectum, anal canal, or vagina. The clamp is then opened, and is made to grasp and lock on the ends of the two fascial strips, the other ends being secured with a hemostat This clamp, holding the strips of fascia, is now pulled back through the tunnel that it has made, which thus places two fascial strips in front of the anal canal, in the subcutaneous tissues The free end of one of the fascial strips is now grasped with a Kelly clamp, which

ence with this operation report gratifying results in the majority of cases. The author has used it in absence of the sphincter The result was a complete failure after the first operation with marked improvement after a second attempt. In the first operation foreign material (ox fascia) was used which became completely absorbed This may be the reason for the failure No trace of the fascial strips could be found at the second operation two years after their insertion. In the second operation autogenous fascia lata strips were used which seem to hold well the parents report marked improvement of the child s condition with only occasional soiling

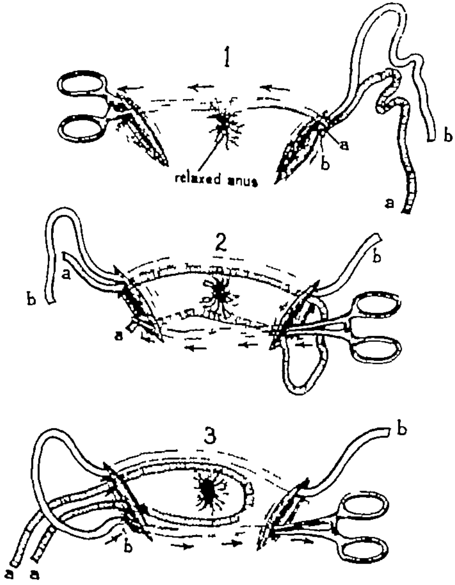


Fig. 311 Anal-sphincter plastic procedure (Stone) *1:* Two fascial strips are to be passed subcutaneously in front of anus. Clamp holding free ends of fascia is shown in position. *2:* One fascial strip *b* is in front of anus. Other one is being passed posteriorly around anus. *3:* Fascial strip is being passed around anus in opposite direction. (H. B. Stone Arch. Surg.)

an enema are administered After the second week, the patient is told to exercise the gluteal muscles at regular intervals daily (See also p 544 of following chapter)

Pickrell and coworkers recently reported an ingenious method of sphincter reconstruction by means of a gracilis muscle transplant They found this new principle effective even in cases of anal incontinence resulting from absence or interruption of the nerve supply to the perineal

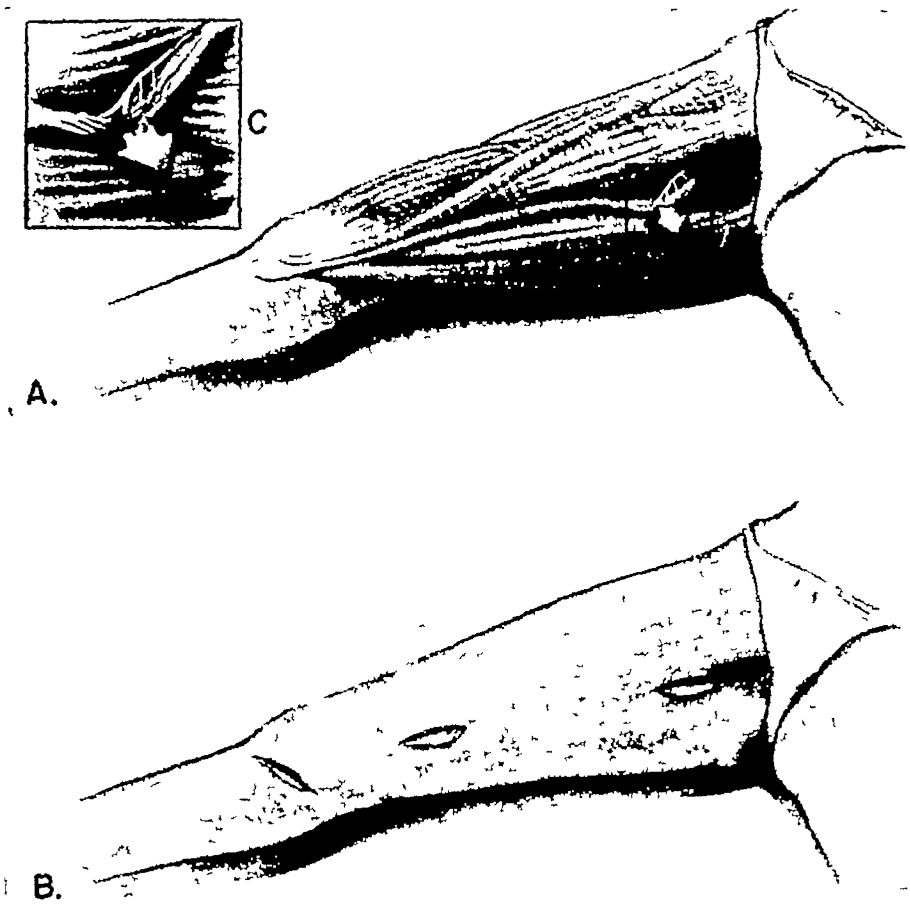


Fig 314 Anal sphincter plasty with gracilis tendon transfer (K Pickrell) *A*· The gracilis is the most superficial muscle along the inner aspect of the thigh, being located at its origin just medial to the tendon of the adductor longus It arises from the lower half of the symphysis and pubic arch and extends below the knee to insert into the tibia in dovetail fashion

B The highest incision in the thigh is made just medial to the tendon of adductor longus in the adductor-gracilis groove or trough The proximal part of the tendon is mobilized with finger dissection to avoid injury to the neurovascular bundle which enters from the lateral side A second incision is made parallel to the muscle over its lower third Traction placed on the muscle through the highest incision will disclose the path of the muscle A third incision is made in an oblique direction along the upper and medial aspect of the tibia to preserve the dovetail insertion of the gracilis into the periosteum of the tibia All incisions are connected by subcutaneous tunnels through which the muscle is mobilized

C The innervation (L2, 3, 4) and blood supply (profunda femoris) enter the gracilis high on its lateral side as a neurovascular bundle Care should be exercised to avoid injury to it. (K. Pickrell, et al., Surgery.)

is pushed in similar fashion from one incision to the other in the subcutaneous tissue behind the anus The clamp is released and the fascial end is drawn out of the second incision so that this strip enters one incision, encircles the anus under the skin, and emerges from the same incision Before the clamp is drawn back, it grasps the end of the other strip It is then withdrawn pulling this second strip with it Thus, the second strip also encircles the anus, but from the opposite side, and its two ends emerge from the opposite incision The finger is then inserted into one of the incisions and feels outward and backward until the mesial margin of the musculus glutaeus maximus is defined. An aneurysm needle or clamp carrying a strong guide thread is then pushed around a substantial bundle of the gluteus muscle This thread is tied to one of

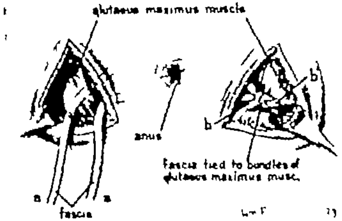


Fig. 313 Fascial ends are tied on right side ready to be tied on left side (H B. Stone: Arch. Surg.)

the ends of fascia lying in the incision and the strip is then pulled around the bundle of gluteus fibers This end of the strip is then tied to the other end of the same fascial strip in a firm square knot with enough tension to close the anal opening snugly but not with strangulating tightness A similar maneuver is carried out on the other side Thus the two fascial strips form closed rings which encircle the anal canal on their inner or mesial curves and provide a bundle of gluteus fibers on their outer curves, but pull against each other and firmly close the anal canal The wounds are closed.

After Treatment The patient is given a liquid diet. He receives 5 cc. of paregoric every two hours for six doses and antibiotics as outlined previously On the fourth postoperative day the diet is changed to soft foods and he receives 30 cc. of mineral oil every night. If there has been no bowel movement on the sixth postoperative day stronger cathartics or

bundle that enters the muscle at its highest part from the deep lateral aspect (Fig 314 insert) The patient is now placed in lithotomy position and the perineal incisions are made as shown in Fig 315 At 12 and 6 o'clock the incision is deepened on each side of the raphae without injuring or perforating the latter The incisions are now connected with each other with a subcutaneous tunnel A tunnel is also made to connect the incision at 12 o'clock with the highest incision at the thigh The tunnels should be wide enough to allow free insertion of two fingers The gracilis muscle is then threaded through the thigh to the perineal tunnel and beneath the anterior raphae (Fig 315c) As the muscle is placed under tension the neurovascular bundle will be seen to enter from the deep lateral aspect of the origin of the gracilis (Fig 315a) If it is not seen the muscle has not been mobilized high enough The tendon and muscle are threaded around the anus in a clock-wise direction to make a complete circle The tendon is passed beneath the anterior raphae at six o'clock If possible the tendon is threaded beneath the anterior pulley a second time When the muscle is large and bulky there is not sufficient space beneath the raphae at 12 o'clock to admit the tendon a second time, then the tendon is passed externally to the raphae The meticulous closing of the subcutaneous tissue and skin is of utmost importance

An incision is made over the tuberosity of the left ischium, in other words, opposite to the donor leg (The right leg being the donor leg in this case) An opening is made at three o'clock to expose the tuberosity as well as the lateral aspect of the levator ani (Fig 315A) A periosteal flap or pulley is elevated from the tuberosity of the ischium (Fig 316A) A pulley is also made from the levator ani The dovetail tendonoperiosteal insertion of the gracilis is then split for one centimeter or more Half of the dovetail is anchored with sutures of silk either beneath or into the periosteal flap over the prominence of the ischium, while the remaining half is anchored securely to a pulley of levator ani (Fig 316A)

In patients who are heavy or obese, it is somewhat easier to anchor the tendon end to the medial end of the inguinal ligament, the lacunar ligament or the fixed heavy portion of the adductor longus tendon of origin, on the side opposite the muscle transplant (Fig 316C) The tendon is anchored in the following manner An incision, approximately two inches in length, is made just below the fold of the groin, over the medial end of the inguinal (Poupart) or lacunar (Gimbernat) ligament The incision is deepened to expose the ligament just lateral to the pubic tubercle, as the spermatic cord in the male is retracted superiorly By retracting the inferior skin edge downward, the adductor longus tendon

muscles (spina bifida etc.) but according to the author's experience it is not successful in cases of dense scarring around anus and rectum

Technic (Pickrell et al.) (Figs 314–316) After consultation with the urologist and neurologist, and preoperative studies and preparation (see p 538) have been made the lower extremity is chosen that has the stronger gracilis muscle. With the legs widely abducted the muscle is palpated as the most superficial muscle along the median aspect of the thigh Three incisions are made at the thigh as outlined in Fig 314

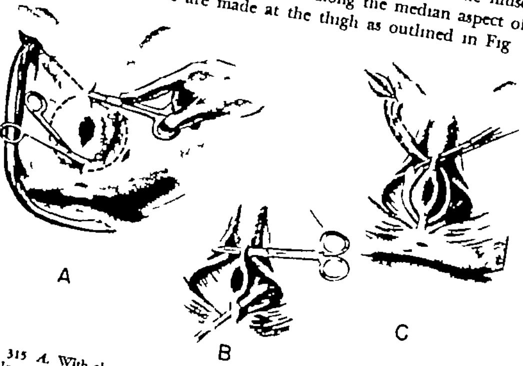


Fig. 315 A. With absence of muscle tone and structural support, the perineal floor will bulge when the patient is placed in exaggerated lithotomy position. Incisions are made in the anterior (12 o clock) and posterior (6 o clock) commissures, being careful to avoid injury to the raphae. A subcutaneous tunnel is made around the anus. A tunnel is also made to connect the highest incision in the thigh with the incision at 12 o clock.

B When possible pulleys are constructed from the anterior and posterior raphae They are not essential, however

C The gracilis tendon and muscle are threaded through the tunnels and beneath the pulleys, if they have been constructed. (K. Pickrell, et al., Surgery.)

From the middle incision while the thigh is held adducted and the knee slightly flexed the gracilis tendon is identified just posterior to the sartorius tendon It is freed distally by blunt dissection as it passes behind the median condylus femoris and curves around the median condylus tibiae By pulling the muscle the insertion of its tendon can be visualized through the lowermost incision The entire fish tail like part is preserved and severed from its insertion at the tibia and withdrawn through the middle incision From the uppermost incision the muscle is freed bluntly and withdrawn Care must be taken to avoid injury to the neurovascular

The final insertion of the muscle is not decided upon nor fixed until the legs have been brought down into line with the body, then adducted and abducted to make absolutely sure that the anus is tight and very snug When attempting to insert the finger, over which a second glove has been placed, a cervix-like channel should be encountered All operative incisions are closed without drains, in layers with sutures of silk The perineal incisions are sealed with collodion No perineal dressing is required A snug compression dressing is applied to the thigh

After Treatment. The urological consultant will advise regarding the removal or insertion of a catheter Antibiotics are administered Patient is given only liquids for the first several days, then is placed on a low residual diet On the seventh day well-balanced meals are begun and are supplemented with mineral oil at bedtime Within several days the patient will become conscious of a feeling of abdominal fullness He is then placed on a commode and with the thighs adducted and the trunk flexed he is taught to relax the perineum and apply manual kneading pressure to the lower abdomen If cramps are felt it is possible that the gracilis cuff is too tight, gentle dilation will cause it to relax Subsequently, daily training periods should be scheduled each morning, an oil retention enema may be necessary if a fecal mass develops in the rectum

Partial Defect of Sphincter Muscle

Partial defects of the sphincter can be successfully bridged by Blaisdell's procedure, which consists in a gradual transplantation of sphincter-bearing flaps The method has been found simple, versatile, and effective

Technic (Figs 317–318) For preoperative preparation of the patient, see p 538

Stage 1 (Fig 317 *a-b*) A "goblet" incision is made on each side of the defect, with the cavity of the goblet surrounding the respective edge of the preserved part of the sphincter The incision is made deep enough to include functioning muscle After separation of the wound edges, a tongue-shaped flap, *A* (Fig 317, *a*), of muscle-bearing tissue is formed, mobilized, and moved downward to point *A′* It is held in this position with a buried suture of stainless-steel wire The skin wound is closed with silk sutures The same procedure is performed on the other side To counteract tension, a pursestring suture is inserted around the anus, as depicted in Fig 317, *b,* and is pulled and tied tightly

Stage 2 (Fig 318) After a few weeks, a curved incision is made over the remaining gap Again the incision is carried the greatest depth of the sphincter muscle After separation of the wound edges, the extreme ends

is exposed A subcutaneous tunnel is then formed by finger or blunt scissors or clamp dissection to connect this incision in the groin with the incision at 12 o clock in the perineum A pulley or tunnel is made beneath the lacunar ligament or the adductor tendon The tendon end of the gracilis is then pulled through the subcutaneous tunnel into the groin then beneath and over the pulley of the lacunar ligament or the tendon of the adductor longus The tendon end of the gracilis is anchored securely both to itself and to the lacunar ligament on each side (Fig 316 C) using sutures of silk The incision in the groin is then closed in layers using interrupted sutures of silk

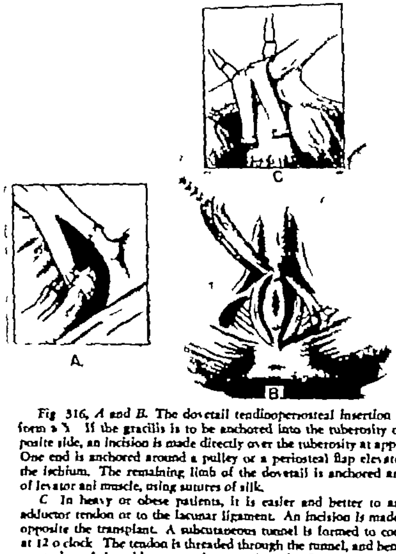
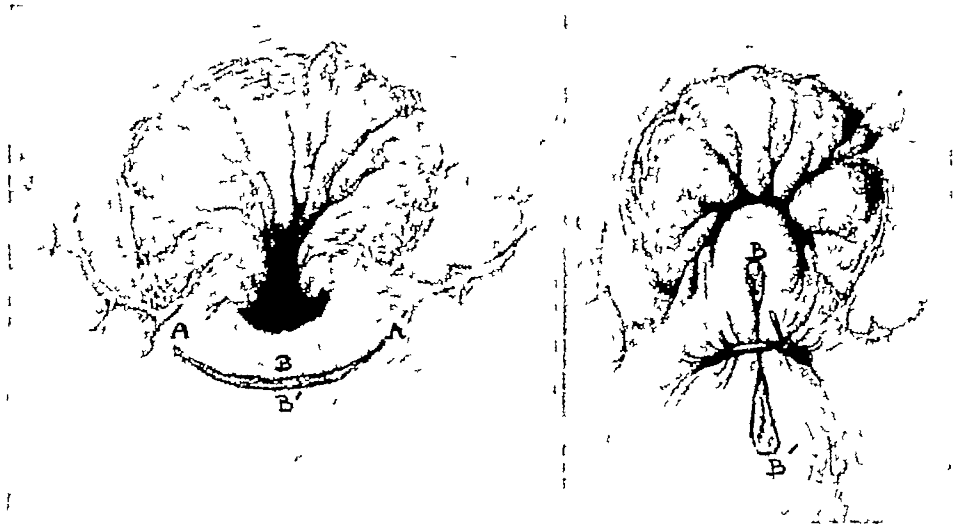


Fig 316, *A* and *B*. The dovetail tendinoperiosteal insertion of the gracilis is split to form a Y. If the gracilis is to be anchored into the tuberosity of the ischium on the opposite side, an incision is made directly over the tuberosity at approximately 3 to 4 o clock. One end is anchored around a pulley or a periosteal flap elevated from the tuberosity of the ischium. The remaining limb of the dovetail is anchored around a pulley or bundle of levator ani muscle, using sutures of silk.

C In heavy or obese patients, it is easier and better to anchor the gracilis to the adductor tendon or to the lacunar ligament. An incision is made in the groin on the side opposite the transplant. A subcutaneous tunnel is formed to connect it with the incision at 12 o clock The tendon is threaded through the tunnel, and beneath the lacunar ligament or tendon of the adductor on the opposite side. The gracilis tendon is then anchored to itself and to the ligament on each side using sutures of silk.

D: The anal orifice is constricted and closed by a collar of contractile muscle Sufficient tension should be placed on the gracilis to insure that the orifice is very tight—like a cervix. Remember that the orifice must be air and watertight and must be able to withstand considerable pressure upon it. (K. Pickrell, et al., Surgery)



a b

Fig 318, *a* Anal-sphincter plastic procedure (Blaisdell) Stage 2 A curved incision is made over remaining gap It is carried to the greatest depth of sphincter muscle. *b* *A* has been approximated to *A'* with deep-buried wire suture Wound is closed with silk sutures (P C Blaisdell Surg, Gynec. & Obst)

Variation: For larger defects, more than two stages are recommended, in small defects, only one stage—the second stage, as just described—may be needed

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of the incision with the free edges of the functioning sphincter beneath are united with buried wire sutures thus changing the transverse direction of the wound into a longitudinal one The skin edges are united with silk sutures A pursestring suture is inserted around the anus

Fig. 317 *a* Anal-sphincter plastic procedure (Blaisdell) Stage 1: "Goblet" incision is made on each side of defect. Cavity of goblet surrounds respective edge of preserved part of sphincter thus forming tongue-shaped flap, *A*, of muscle-bearing tissue. *A* is to be transplanted to *A* (P C. Blaisdell: Surg., Gynec. & Obst.)

Fig. 317 *b*: Deep-buried wire sutures of fine stainless steel hold *A* approximated to *A* (*lower*) (see also Fig. 317 *a*) Wound is closed with silk sutures. Pursestring suture is inserted around anus to counteract tension.

DIVISION FOUR

THE EXTREMITIES

XX

INTRODUCTORY ASPECTS OF THE EXTREMITIES

THE principles of reparative and reconstructive surgery as applied to the extremities are applicable to all parts of the extremities. From the functional standpoint however hand and foot must be considered as distinct units necessitating a certain variation and specification in some of the reconstructive principles Hence reparative and reconstructive surgery of the extremities is discussed under the following section headings (1) the Extremities Other than Hand and Foot, (2) the Hand and (3) the Foot. The problems discussed are those in which the general surgeon as well as the general plastic surgeon is interested. Those matters belonging strictly to other specialized fields such as orthopedics have been omitted.

To furnish a proper division of this rather broad field the material is divided into anatomical units certain reparative problems applicable to those units have been selected, and are discussed under the following headings Skin Subcutaneous Tissue, and the Fasciae the Muscles and Tendons the Nerves the Blood Vessels the Bones the Articulations

Anesthesia in Surgery of Extremities

The agents and methods for operation on the upper extremities are *ether* either alone or in combination with the gases the *gases* such as nitrous oxide ethylene and cyclopropane either alone or in combination with solution of sodium pentothal Local anesthesia is obtained with *procaine* either by infiltration or by nerve block or by a combination of both The various nerve blocks which are possible are the brachial

diate skin-grafting in acute surface defects is applicable not only to losses involving the skin alone, but also to deeper defects of the subcutaneous tissue which cannot be closed by skin-sliding and which do not require a flap The grafts may then be considered as biological dressings promoting quick and better healing

Deep Defects: These defects, exposing important structures such as tendons and bones, require *flaps* for their closure If a flap cannot be applied immediately the defect may be closed temporarily with a skin graft, which provides protection against infection and necrosis In some instances, the flap can be taken from the immediate neighborhood A typical example is the closure of a longitudinal defect of the covering tissue in front of the tibia after compound fracture or osteomyelitis *Such a defect is closed with two longitudinal bridge flaps, which are* mobilized from the immediate neighborhood and, after being shifted into the defect, are held together with sutures The secondary defects lateral to the flaps are covered with skin grafts (Case 108, p 996) In the majority of cases, however, flaps must be transplanted from distant parts Wherever a direct transfer is possible—as, for instance, an abdominal flap to the arm (Case 107, p 994) or a flap from the thigh or leg of one side to the leg of the other side (Cases 109–111, pp 998–1002)—the open-pedicle-flap method is used (p 73) If the flap is to be transferred by an intermediate carrier, such as the wrist (Cases 103, 106, pp 986, 990), the tube-flap method is chosen (p 78) However, Cannon et al and Edwards have demonstrated, that even in those cases the open jump flap method, using the forearm as a carrier, may be applicable In selected cases of surface defects of the leg, in which sliding flaps are not applicable and distant flaps seem to be the only choice, Deming was able to close them with tube flaps from the calf of the same side

CHRONIC ULCERS

Chronic ulcers—in the majority of cases, involving the lower extremity—are of various origins from disturbance of circulation (varicose veins, arteriosclerosis), from metabolic disorders (diabetes), from trauma (pressure, compound fractures), from infection (osteomyelitis, tuberculosis, syphilis, conditions caused by anaerobic organisms), and from neuropathic disorders (Raynaud's disease, malum perforans)

Concerning treatment, two general principles are outlined (1) The local treatment should be preceded by or at least accompanied by a treatment of the underlying cause No permanent local cure can be expected unless the causative factors are eliminated. (2) An ulcer, after elimination of the underlying cause, should be resurfaced with transplanted skin,

XXI

SKIN, SUBCUTANEOUS TISSUE, AND THE FASCIAE

Defects

ACCIDENTAL DEFECTS

IN THE majority of cases acute defects of skin and subcutaneous tissue are due to trauma The treatment of wounds and burns has been discussed (see Cases 93 94 pp 972 974) Open for discussion then are those wounds which have resulted in actual loss of tissue The type of closure depends entirely upon the width and depth of the defect

Superficial Defects. Superficial losses involving only the skin are best closed by skin-grafting The type of graft ordinarily to be used is a *thick split graft* The full-thickness graft is applicable only under strictly aseptic conditions—after removal of tumors for instance. Full thickness grafts are contraindicated in all traumatic wounds, since the latter are potentially infected (see p 24) In traumatic loss of skin the raw area unless grossly infected, is properly cleansed and débrided, and then covered immediately with a split skin graft, regardless of the lapse of time. Antimicrobic therapy is instituted postoperatively Such a skin graft has a good chance to take.

If the graft takes, the healing process of the wound is much shortened, and the cosmetic and functional results are much better than they would be if the wound were left to granulate It is unfortunate that the popular conception still prevails that one should wait for granulations to develop. The results are comparable to those of wound-healing by primary intention If the graft does not take no further damage occurs except that the superficial raw area of the donor site is added The principle of imme

all of these ulcers can be blamed on varicosities of the superficial veins, particularly in younger people, attention has been turned to the deep venous circulation Bauer, Linton, and others developed the thesis that thrombosis and obliteration of the main deep venous channels of the leg are followed by canalization of these veins, with resultant incompetence of the valves in the deep communicating and superficial veins, and thus become the cause of the leg ulcer

Treatment: It is essential to submit each patient with a leg ulcer to a careful history and clinical examination, including various tests to provide corrolatory evidence of superficial or deep venous incompetence It is beyond the scope of this book to go into these details The fundamental principle in treating a leg ulcer based on venous incompetence is elimination of venous stasis and edema Treatment may be either ambulatory or require hospitalization The local applications recommended for treatment of the ulcer are numerous The nature of the local application is immaterial If the ulcer is grossly infected the patient should be hospitalized—strict rest in bed is essential The ulcer is dressed with gauze soaked in Dakin's solution and alternated with normal saline solution, the dressing should be kept moist constantly (see also pp 27–28) In addition, the infecting organisms should be identified, their sensitivity to the various antibiotics estimated, and proper antibiotic treatment initiated After the infection has subsided the ulcer is covered with xeroform gauze (p 34) and a supportive leg dressing, such as, an elastic bandage, rubber stocking, or Unna's paste boot is applied If the ulcer is not infected the patient can be treated ambulatory with pressure dressings, such as. the "closed" elastoplast technic, which has become popular in Great Britain, Unna's paste boot, and Linton's dressing, which aims to obliterate the superficial veins of the lower leg by means of a large spongy dressing held in place with a very firm dressing

These measures alone, however, cannot be permanently successful unless the underlying cause of the ulcer, namely, the venous incompetence is corrected by an operation If possible, the operation should be delayed until the ulcer is healed If the superficial venous system is at fault, the long saphenous vein and its uppermost branches are ligated at the saphenofemoral junction and the remaining larger veins are "stripped" and excised, and an incompetent perforation is ligated Single incompetent veins communicating between deep and superficial venous systems below the knee are usually associated with varicose ulcers (the so-called "feeder" vein) , these should be taken care of at the time of the ulcer repair Multiple incompetent communicating veins are usually the sequellae of deep thrombophlebitis and should be treated as outlined later

unless it shows a tendency to spontaneous healing The type of transplant depends upon the depth of the ulcer Ulcers in soft tissues can be closed successfully with free skin grafts. Ulcers in which tendons or bare bone (without periosteum) are exposed require the transfer of a pedunculated flap

CHRONIC ULCERS FROM DISTURBANCE OF CIRCULATION

The commonest ulcer resulting from disturbance of circulation is the so-called varicose ulcer As the name implies it is due to circulatory disturbances *from varicose veins* Too often however the varicosities are taken as the obvious cause while other underlying factors are overlooked as has been extensively discussed by Linton Rutter and others as well *as by Barrow in his short but comprehensive monograph* It is generally conceded that the vast majority of these ulcers are due to faulty venous circulation and less often by obliterative arterial diseases The veins of the lower extremity consist of three systems the superficial the deep and the communicating veins The superficial system consists of the saphena magna on the median side and the saphena parva on the lateral side The deep venous system consists of the vena formalis communis superficalis and venae popliteae in the thigh of the venae tibiali anterior and posteria and venae peronealis in the leg The communicating veins connecting the superficial and the deep venous system are few in the thigh and numerous in the leg It has been the common belief that the skin and subcutaneous tissues of the leg are normally drained of blood chiefly by the veins of the superficial system. Stasis in this system resulting from incompetence of the valves causes atrophy of the skin over the anterior surface of the tibia and in the malleolar region The atrophic skin if damaged by trauma or infection breaks down and—owing to impairment of regenerative ability of the surrounding skin—the defect does not become resurfaced. This is the origin of a varicose ulcer Its chronicity or recurrence however is caused by other factors. Local infection is one of them The disturbed circulation and the local necrosis provide excellent soil for the growth of organisms The ulcer becomes enlarged and deeper cicatricial changes take place and may become so extensive as to involve the entire surrounding skin (Case 105 p 989) The skin becomes brownish hard and fixed to the underlying tissue These changes lead to an aggravation of the circulatory disturbance to edema and finally to elephantiasic chronic edema

This classic form of varicose ulcer is most often seen in elderly people and as already pointed out, has been blamed on incompetence in the saphenous or superficial system Recently it has become clear that *not*

If the granulations are flat and pinkish red and the skin surrounding the ulcer is atrophic but movable and not indurated, the graft is applied directly on the granulations. The most suitable type of graft to cover such an ulcer is the small deep graft (p 41) If the granulations are of the sluggish or hypertrophic type, they should be sliced down to a yellow vascularized layer, which constitutes the base of the granulations prior to the application of the grafts If the surrounding skin is indurated by cicatricial changes, the entire involved area—no matter how large—must be excised, together with the base of the ulcer, down to the deep fascia, care being taken not to expose tendons or bone The raw area is covered with a large split graft (Case 105, p 989) Removal of the damaged surrounding skin eliminates the tendency to recurrence, and leads to improvement of the local circulation by relieving constriction The grafted area is covered with a pressure dressing, and the leg is elevated

After-Treatment: The dressing is changed after seven days The leg should remain elevated, with a pressure dressing applied for at least two weeks If parts of the graft do not take, wet dressings (Dakin's and isotonic saline solution alternately) are applied, and the extremity is kept elevated until the entire area has healed. Sometimes subsequent skin-grafting may become necessary When the patient is up and around, he is advised to wear a supportive dressing until the graft has assumed normal color.

Chronic Undermining, Burrowing Ulcers from Infection

In 1935, Meleney described a type of ulcer which he called the "chronic undermining, burrowing ulcer" He found its cause to be the microaerophilic hemolytic streptococcus, which may enter the tissues either through an accidental wound or an operative wound or through a lymph gland from a distant source He reported successful treatment of the lesion with zinc peroxide His findings and success with the zinc peroxide treatment have been confirmed—often dramatically

This ulcer can occur on any part of the body surface. The lesion is characterized by prolonged suppuration, with the gradual development of an ulcer with undermined rolled-in skin margins and sinuses, which tend to burrow beneath the skin or into the deeper tissues, along lymphatic channels, veins, or fascial planes The base of the ulcer is covered with grayish, gelatinous, anemic, and shaggy granulations Gangrenous processes are entirely absent. The author has also found the anaerobic hemolytic streptococcus in chronic ulcers without undermined rolled-in skin margins and for which no other cause could be established (Case 104, p 988) They have invariably responded to the zinc peroxide treatment

If the deep venous system is at fault, in other words thrombosis and obliteration of the deep veins are present it is thought dangerous to ligate the superficial system. The large experience of Rutter Linton Barrow and others contradicts this opinion Linton not only ligates and strips the superficial veins of the lower leg but also ligates the communicating veins between the posterior tibial and the superficial veins interrupts the vena femoralis superficialis at its junction with the profunda, and ligates and strips the long saphenous veins Rutter however advocates only ligation of the superficial system in most of the cases while ligation of the deep system (popliteal vein) is carried out only when the following four requirements are fulfilled *a*, chronic or recurring ulceration not responding to other less radical treatment including the obliteration of all superficial varicose veins *b* severe and crippling pain especially if it is of the "bursting" type *c* absence of severe edema d positive venographic evidence of dilatation and irregularity of outline of the popliteal vein

Under such treatment the ulcer which as a rule is situated in the malleolar region or over the anterior surface of the tibia, may remain healed However the resulting scar which is often surrounded by atrophic skin may be unstable and break down after trauma or infection and—owing to impairment of regenerative ability of the surrounding skin—the defect does not become resurfaced The ulcer then becomes chronic cicatricial changes take place beneath and around the ulcer and may become so extensive as to involve the entire surrounding skin The skin becomes brownish hard and fixed to the underlying tissues These changes lead to an aggravation of the circulatory disturbance to edema and finally to the elephantiasic chronic edema.

Preparation of Local Area As mentioned in the foregoing, elimination of the venous stasis and edema must be the preliminary treatment. The patient is kept in bed with the leg elevated. As a rule in chronic cases the veins have been ligated and injected previously If not this should be performed unless contraindications such as cellulitis and phlebitis exist. The next step is the control of any infection as outlined above.

Then follows the preparation of the granulations for skin-grafting A daily bath of the leg in warm saline solution followed by pressure dressings and elevation of the extremity is of the utmost importance The granulations themselves are treated as has already been described on pp 27–28

The question now arises whether the ulcer should be excised prior to the application of the graft. The following rules have proved valuable

when extraneous moisture is present. For that reason, not only must the zinc peroxide be applied to every part of the wound surface, but the wound surface must then be covered with a double layer of fine-meshed gauze soaked in the suspension. This helps to maintain contact, but must, in turn, be covered by gauze compresses or sheet cotton wet with water The whole dressing is then sealed with petrolatum gauze or, better still, gauze impregnated with zinc oxide ointment, which is more impermeable to the air and does not irritate the surrounding skin. This impermeable covering should have a wide margin around the wet compresses, so that any slight movement of the part will not displace them In leg or forearm ulcerations, it is possible at times to use rubber sheeting to seal the dressing, but this is not practical on other parts of the body.

This dressing is changed daily Antibiotic treatment is imperative In those ulcers with overhanging skin edges and undermined areas and sinuses, proper excision should be carried out to provide adequate contact of the material with the tissues As soon as the area is clean and covered with pinkish, flat granulations and thus the ulcer changed into a clean granulating wound, a thick split skin graft should be applied to the raw area The graft is applied directly upon the granulations

Deformities

CICATRICIAL CONTRACTURES

Dermatogenous or desmogenous contractures are caused by the destruction of the surface and deeper parts of the surface tissue, as after extensive burns or less often they are congenital from amniotic furrows (see p 147) The traumatic contractures usually occur at the flexor surface of the extremities or at the junction of limb and trunk In the majority of cases, much can be done by early skin-grafting to avoid them There are, however, instances where a skin-graft operation is contraindicated because of the patient's impaired general condition or where large grafts are not available or fail to take In such cases, proper immobilization of the affected limb may counteract the contracting forces during the waiting-period When the knee or elbow joint is involved, the extremity is immobilized on a molded plaster-cast splint Plantar flexion of the foot at the ankle joint can be avoided by placing a wooden box at the foot of the bed so that the patient can brace the injured foot against the box, or a molded plaster-cast splint that includes the foot may be applied Contractures of the axilla are difficult to counteract The arm should be placed in right-angular abduction, and kept in this position with the aid of pillows These measures should not, however, cause pain or undue discomfort

By careful anaerobic as well as aerobic studies, Meleney found the microaerophilic hemolytic streptococcus to be invariably present Laboratory studies showed them existing between the aerobic hemolytic streptococci and the strictly anaerobic hemolytic streptococci. The diagnosis depends upon thorough aerobic and anaerobic cultivation

Treatment The sulfonamides and antibiotics in spite of acting dramatically in the early stages of an acute infection caused by the hemolytic streptococcus, are only of little value in the chronic stage, when the hemolytic streptococcus becomes adapted to an anaerobic environment. It is in this stage of the disease where application of *zinc peroxide* has proved to be of enormous value since it provides a high oxygen tension in the tissues for a considerable period of time

The secret of the success of zinc peroxide however depends upon three fundamental requirements as Meleney emphasizes. The first is the material itself The DuPont Company which manufactured the zinc peroxide originally used and found to be effective, has been the only chemical company consistently able to manufacture effective material The importance of certain physical properties of this material are of fundamental importance because while the chemical content of zinc peroxide in the powder may be high the oxygen may not be mobilized or made available Preliminary heating in a dry oven at 140° C for four hours not only sterilizes the powder but mobilizes the oxygen When added to sterile distilled water after the sterilization and activation process effective material always flocculates quickly as a soft curdy mass leaving a clear supernatant fluid and it is soon lifted up by the formation of oxygen bubbles This test should always be made before using any preparation

The second most important feature of the treatment is to obtain close contact between the zinc peroxide and the infection. With many of these ulcers, there are deep undermined skin flaps and deep sinuses which prevent close contact of the medication unless the advancing margins of the infections are excised

The third essential feature of the treatment is the prevention of evaporation The oxygen is conveyed from the zinc peroxide to the tissue by means of water When zinc peroxide is suspended in water oxygen is given off into the water hydrogen peroxide is formed and the oxygen is then transferred to the surroundings. This leaves H_2O which then takes up more oxygen from the zinc peroxide. If the zinc peroxide dressing is allowed to dry this action stops or is greatly diminished, and the dry material may mechanically irritate the wound whenever the patient shifts his position The tissue fluids and the body exudates may act as catalytic agents but the activity of the zinc peroxide suspension is at its best only

If in spite of all these measures, a contracture starts to develop nothing forcibly should be done to overcome it unless the patient is ready for operation Blair and Brown and their associates, as well as Koch and others, have pointed out that a raw surface in the flexor region of joints often decreases in size not so much by the overgrowth of epithelium from the periphery of the wound as by drawing in of the adjacent tissues If the process is permitted to take place without interference healing goes on rapidly If on the contrary the contracting joint is irritated by repeated forceful dressings there will be a greater production of fibrous tissue followed by more extensive shrinkage or if the extremity is forcefully stretched under anesthesia and fixed in this position wide fissures are opened in the granulating wound with the possibility of infection delay of healing and production of larger and denser scar tissue. What really is needed in such a case is the early covering of the raw surface with a skin graft regardless of the degree of contracture. After healing has taken place proper physical therapy should be instituted to lessen the contracture. Further operative procedures however may become necessary to overcome a remaining deformity

To correct a contracture several procedures or a combination of various procedures are available If the contracture is caused by web formation and the surrounding skin is pliable one or several Z-operations provide the procedure of choice. In contractures due to broad dense scars the latter are incised or excised the contracture is reduced and the resulting defect is covered either with a skin graft or with local or distant flaps. The profession is indebted to J B Brown for having perfected the technic of skin-grafting to such a degree that it has become the method of choice in the majority of contractures where a flap formerly was considered indicated

Axilla

Z-Operation (Case 95 p 975) Indication for this operation arises when the contracture is due to binding webs and the surrounding skin is pliable Sometimes the web is so long as to necessitate several Z s. Sometimes the arm is bound to the chest by several webs which all have to be broken up For technic of the Z-operation see p 147

Use of Graft (Cases 97–99 101 pp 978–980 984) This method is indicated whenever the contracting scar is broad but during the repair vessels and nerves do not need to be exposed or if exposed can be covered by surrounding fat tissue. The contracture is released with a transverse relaxation incision through the entire thickness of the scar Excision of the scar is rarely necessary The incision should not be made through the center of the scar but near the chest wall This will shift the defect rather

by additional incisions to the original longitudinal incision. The objects of such a procedure would be (1) to interrupt a longitudinal direction of the original incision and to change it into a transverse or oblique course, and (2) to increase its length The condition could now be compared physically to an accordion

The same result can be achieved with a much simpler procedure, by changing the straight course of the longitudinal incision into a spiral form (Case 102, p 985) The course of the incision is marked out preoperatively with one of the aniline dyes One third of the spiral should lie anteriorly to the border of the musculus pectoralis major, two thirds posteriorly to it in the axilla

There are two precautions to observe (1) to avoid making the spiral cut too steep and too high, (2) to mark two opposite points at the extreme parts of the curves with a drop of methylene blue injected percutaneously. This will facilitate correct adjustment of the wound edges later on.

Elbow Joint

The underlying principles in repairing flexor contractures of the elbow joint are the same as those previously described If a Z-plastic procedure is possible, partial or even complete relief can be achieved In some instances, a combination of the Z-operation and skin-grafting will lead to success In extensive contractures, particularly those of long standing, the contracted biceps and the involvement of the joint structures may offer a major obstacle in reducing the contractures When opening the contracture, great care should be taken not to injure main vessels or nerves and not to expose tendons If it is found impossible to relieve the contracture completely without exposing or endangering those structures, one should be satisfied with a temporary partial success, that is, to skin-graft the defect, encase the extremity in a plaster cast, and repeat the procedure after healing has taken place The first cast should not be changed for at least two weeks unless there is evidence of infection.

In those extensive cases in which exposure of the contents of the cubital region and tendon-lengthening must be anticipated, the use of a flap becomes primarily the method of choice A direct transfer of the flap can be planned if it is possible to raise the flap from the lateral chest region on the same side The direction of the flap is transverse, the pedicle (compare with Case 107, p 994) located anteriorly opposite the contracted joint Or the flap is taken from more distant regions and then transported by way of the wrist of the other arm Such a flap should be tubed (Case 103, p 986)

If lengthening of the biceps tendon becomes necessary, the Z-method

The dressing is changed after ten days active exercises should be undertaken after the third postoperative week One of the simplest is exercise on the swing If in spite of active and passive exercises the contracture should recur to some degree another skin-graft operation should be performed

Variation There are cases of contracture where a strip of normal or at least pliable skin is left in the depth of the axilla. In these cases the relaxation incision is not carried through the axilla but along the median border of the pliable skin portion that is, along the chest wall (Burton) (Case 101 p 984 [right axilla]) If the arm is forcibly abducted the skin—partly by dissection and partly by being pushed laterally—moves upward and is held in the new position with sutures or it may be turned outward as just discussed. The remaining defect at the chest wall is skin-grafted as also described in the foregoing

Use of Flap In those cases of extensive contracture in which the binding scar consists of heavy dense fibrous tissue necessitating partial excision of the scar and exposure of vessels and nerves to overcome the contracture without available fat tissue to cover these structures transplantation of a flap for covering the defect becomes indicated Another indication for the use of a flap is previous failure to correct the contracture by the free-graft method The flap is preferably taken from the neighborhood (chest or back) and as a rule needs to be made so long that delayed transfer becomes necessary (Case 101 p 984 [left axilla]) Occasionally a flap can be rotated from the immediate neighborhood into the defect in one stage and the secondary defect, consisting of the original flap bed, be skin-grafted (Case 100 p 982) Two flaps may be needed. Davis suggests raising one from front and the other from back the free ends being sutured together

Prevention of Contractures after Radical Removal of Breast A popular incision in radical operations for cancer of the breast is the elliptical incision around the diseased breast and its longitudinal extension upward along the lateral border of the musculus pectoralis major It is this latter part of the incision which in a certain number of cases causes limitation of motion of the arm in the shoulder joint later on. After removal of the pectoral muscles the incision or rather the resulting scar comes to lie across the axilla. If this scar contracts it becomes a bridle scar or a binding web In extensive cases the contracture can be corrected by a Z-operation

To counteract the possibility of a contracture by a *binding web* it seems logical to perform the Z-operation with formation and interposition of two triangular flaps at the time of the first operation This can be done

are troublesome and difficult to correct It would be inadvisable to remove the whole scar, for it would be impossible to obtain sufficient skin with which to cover the defect To relieve these large, thick scars, Davis' relaxation procedure is a good one The contracted region is put on a stretch, and the most binding area or areas are located and marked out The scar is divided completely through its full depth until normal tissue is reached Sometimes, radiating incisions from the tight margins are necessary to complete the relaxation If, after the incisions are made, the scar is found to be very thick, excision of a wedge-shaped slice of the deeper layer is advisable, so that the thinned surface edges may be drawn downward and attached to the normal base by a few sutures The defects are now covered with split skin grafts After application of a proper pressure dressing, the leg is supported by pillows and sand bags, and thus semi-immobilized If the flexion deformity could not be overcome in one stage, the leg is placed under some sort of traction, on a Braun-Bohler type of splint, for instance Subsequent relaxation and and skin-grafting are performed after the wounds have healed

In extreme and rigid cases, one of the relaxation incisions should be made over the spina iliaca anterior superior, and after incision of the scar, a tenotomy of the musculus sartorius, musculus tensor fasciae latae, and the fascia lata should be performed directly below the spina In adductor deformity, the relaxation incision is laid over the adductor region close below the pubic bone, and the musculus adductor longus and musculus gracilis are tenotomied The defects are covered with skin grafts

Knee Joint

The principles in correcting contracture of the knee joint are similar to those already enunciated Flaps are rarely needed If needed, they are taken from the opposite thigh or transferred from the opposite thoraco-epigastric region by way of the wrist of the same side. The relaxation incision is led transversely through the most binding area Care should be taken not to expose the popliteal contents, particularly the tendons. If the contracture cannot be overcome in one stage, the defect is skin-grafted, the extremity encased in a plaster cast, and one or more similar procedures performed subsequently The first plaster cast should not be changed for at least two weeks, unless there is evidence of infection

In this way, most of the contractures, even the extensive ones, can be repaired. There are, however, cases where the contractures can be overcome in the longitudinal direction, but the result be spoiled by a posterior subluxation of the tibia due to shortness of the posterior ligaments (Case 96, p 976) O'Donaghue recommends application of horizontal and

is effective (compare with Fig 321) However in a few instances the contracture of the biceps is so extensive that even the Z-operation is insufficient to permit complete reduction If such is the case one should not hesitate to sever the biceps tendon and either transfer its insertion to a position higher up (see p 575) or permit the tendon to retract without suturing (Case 105 p 986) It is amazing that the lifting power of the affected arm is hardly impaired.

In cases where almost the entire joint region is enveloped in a large, thick contracted scar a relaxation procedure—such as later described in the discussion on contractures of the hip joint—should be given a trial

Wrist

Contractures of the wrist can involve the extensor side as well as the flexor side and are, as a rule associated with contractures of the fingers They are repaired by the use of grafts or flaps, the proper choice depending entirely on whether the tendons must be exposed during the dissection or remain unexposed. The binding scar should be carefully dissected from the underlying tendons, while the latter are gradually stretched. If possible a thin layer of scar should remain on the tendons this makes the use of a thick split graft or even of a full thickness graft possible If the contracture cannot be overcome without wide exposure of the tendons, one abandons further dissection proceeding with skin-grafting of the raw area and planning subsequent similar repair work (see foregoing discussion) Such a plan of gradual repair is particularly advisable in cases where the tendons have been found too tight. Sometimes freeing the tendons is completed in the first operation Then however the use of free grafts cannot be considered. A flap is now indicated. The usual type is the open abdominal flap from the *opposite* side. A flap is also indicated in cases which need later repair work of tendons Immobilization of the grafted area should include the fingers and is performed as described on p 690 Sometimes in a flexion contracture of the wrist of long-standing the carpal bones become subluxated dorsally and resist dorsal extension after release of the contracting forces on the flexor side. It then becomes advisable to remove the proximal row of the carpal bones and arthrodese the wrist in the position of function (see p. 762)

Hip Joint

Flexion contracture of the hip joint can be almost always corrected with the use of grafts. The general technic is similar to that described in the former discussions. Old extensive, contracted, thick and adherent burn scars, which may involve thighs pubic region and abdominal wall

and lengthened (For technic of tendon-lengthening, see Figs 321, 322) The contracted posterior ligaments and capsule of the ankle joint may need relaxation incisions, care being taken not to injure the tibial vessels and nerve

ELEPHANTIASIS

Acquired Elephantiasis

The so-called "idiopathic elephantiasis" (elephantiasis arabum) is an acquired disease, and may involve legs, arms, genitalia, or face It is preceded by lymphedema, which may be due to removal of infected or carcinomatous lymph glands or to increase of the lymph flow, such as is seen after thrombophlebitis or in association with varicose veins. The endemic form of elephantiasis, rare in this country but not infrequent in the tropics, is caused by the Wuchereria bancrofti (Filaria sanguinis-hominis) or other species of Filaria

The underlying pathology of elephantiasis is characterized by two main features: the enlargement of the lymph vessels and a chronic inflammatory fibrosis of the derma and the subcutaneous tissue. The important part is that the superficial lymph system alone is involved, even in advanced cases, and this system is definitely separated from the deep lymphatic system by the aponeurosis covering the muscles. Kondoleon, with an idea of connecting these two systems by removing a large amount of the aponeurosis, modified Lanz's method and devised an operation which has been popularized in this country and improved by Sistrunk. The operation consists in removing a large amount of skin and subcutaneous tissue, together with the fasciae Recently the operation has lost popularity since many failures have been reported Peer, however, recommends its merits to reduce the lymphedema of the arm The theory of establishing a communication of the superficial and deep lymph-systems by this operation is no longer tenable The new operation, as devised by Macey in 1940, and modified by Poth consists of the removal of the affected skin and subcutaneous tissue of the entire leg, with the exception of the toes, the sole of the foot, and a small strip over the Achilles tendon The raw surface is covered with thick split skin grafts followed by application of a pressure dressing and immobilization in a plaster cast for seven days Good results from this operation have been reported by Blocker, Farina, Kirschner, Schuchard, Scriba, Gibson and Tough, and others As a preoperative measure, it is advisable to keep the patient in bed two weeks with the leg elevated and firmly bandaged to reduce the edema as much as possible Every source of infection should be checked. Daily tub baths and thorough cleansing of the leg with soap and water are of benefit

vertical traction to the legs. In extensive cases however, traction alone is not successful The author has been able to reduce the subluxation as evidenced clinically and roentgenologically but as soon as traction was removed the subluxation recurred within a few days Hence, it is recommended that the subluxation be reduced under traction followed by application of a plaster cast with incorporation of the pins. The cast should be applied while the leg is suspended in traction The pins and the anterior half of the cast are removed after two weeks while the posterior half is kept to be applied during the night. Active exercises are instituted Resistance exercises have been found particularly valuable placing one sandbag beneath the leg another upon the thigh and then instituting active motion of the knee Walking is also permitted.

In contractures due to extensive heavy thick scars relaxation incisions as previously described are of great benefit In rare instances where the contracted flexor muscles present the main obstacle tenotomy of the latter should be performed The tenotomy should be made oblique Before one tenotomizes the biceps the peroneal nerve running mediad and close to the tendon should be exposed and held away The deep portion of the biceps insertion should be left behind to avoid separation of the important ligamentum collaterale fibulare The tendon of the musculus semitendinosus, musculus semimembranosus, and musculus gracilis are tenotomized on the median side. In reducing these extreme contractures one should avoid a posterior subluxation of the tibia by overstretching the contracted posterior ligaments and should be satisfied with a temporary partial success

Ankle Joint

Extensor deformities (dorsiflexion) are treated like those of the wrist. Moderate flexor deformities (plantar flexion) are treated by gradually stretching the achilles tendon and replacing the binding scar by skin grafts The leg is encased in a plaster cast after each procedure Severe flexor deformities are the most difficult to handle. Generally speaking the gradual relaxation procedure just described is the most satisfactory although time-consuming If the contracted achilles tendon is found to be the main obstacle requiring lengthening the problems mount. Lengthening of the tendon should go hand in hand with replacement of the covering scar Simple skin-grafting after wide exposure of the tendon cannot be entertained Hence the entire scar should be excised prior to the tendon lengthening and be replaced by a flap preferably one taken from the other extremity (compare with Case 109 p 998 Case 110 p. 1000) After the flap is healed in place the tendon is exposed

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In 1892 Milroy described a hereditary form of lymphedema. This disease is characterized by its familial incidence, lymphedema and elephantiasic enlargement of the extremity, usually of the lower extremities. As a rule both sides are involved. Unilateral involvement, however, and negative family history have been reported (personal communication from Dr Fred Hartmann). There is no evidence of lymphatic obstruction and of fibrosis. The cause is unknown. For this type of elephantiasis operative procedures are of no avail, as the author can confirm from personal experience. The treatment consists in the use of supportive dressings, such as elastic bandages or rubber stockings, and massage to control the edema.

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in the fossa supraspinata of the scapula, proceeds under the acromion and inserts into the uppermost of the three impressions of the tuberculum majus humeri The musculus infraspinatus originates from the fossa infraspinata and inserts into the capsule of the shoulder joint and the tuberculum majus The musculus teres minor arises from the axillary border of the scapula and inserts into the inferior impression of the tuberculum majus These three muscles form near their insertion a musculotendinous cuff Aside from forming the floor of the subacromial bursa the most important role is initiation of abduction of the arm in the shoulder joint They do this indirectly rather than directly by furnishing a fulcrum for the head of the humerus in the glenoid they hold the head firmly against the glenoid and depress it and keep it during abduction as well as during the descent in relation to the glenoid fossa If they are torn the humeral head cannot be stabilized in the glenoid and upon attempt of abduction it becomes displaced by the vertical contraction of the deltoid beneath the acromion

Ruptures usually occur within the musculotendinous portion of the cuff They vary in degree from a tear of few fibers of the tendon, with or without involvement of the capsule or the bursal side of the cuff, to tears involving the full thickness of the cuff, and to massive avulsions whereby the joint capsule and the floor of the subacromial bursa also are torn and a communication of joint and bursa exists Small tears which cause no instability of the joint cannot be distinguished clinically from sprains However, large tears and particularly the complete tears, aside from pain, cause functional disorders through inability to abduct the arm actively or, at least, difficulty in initiating abduction Passive abduction is possible The degree to which normal function is impaired depends upon the extent of the rent, as well as upon secondary changes in the adjacent structures, for instance, Mosley demonstrated in two cases of complete rupture, restoration of full movement after locally anesthetizing the area with procaine, and DePalma found complete tears of the cuff in nine shoulder joints, obtained postmortem from individuals who were not aware of any impairment of function prior to their death On the other hand, a moderate tear in individuals with extensive degenerative lesions in the rotator cuff, from physiologic or traumatic wear and tear, may lead to marked impairment of function From these clinical observations it is obvious that a sufficient time interval (six to eight weeks) should be allowed before deciding on conservative or surgical treatment, depending entirely upon severity of symptoms and dysfunction (McLaughlin, DePalma)

XXII

THE MUSCLES AND TENDONS

Traumatic Defects

HERNIA OF MUSCLES

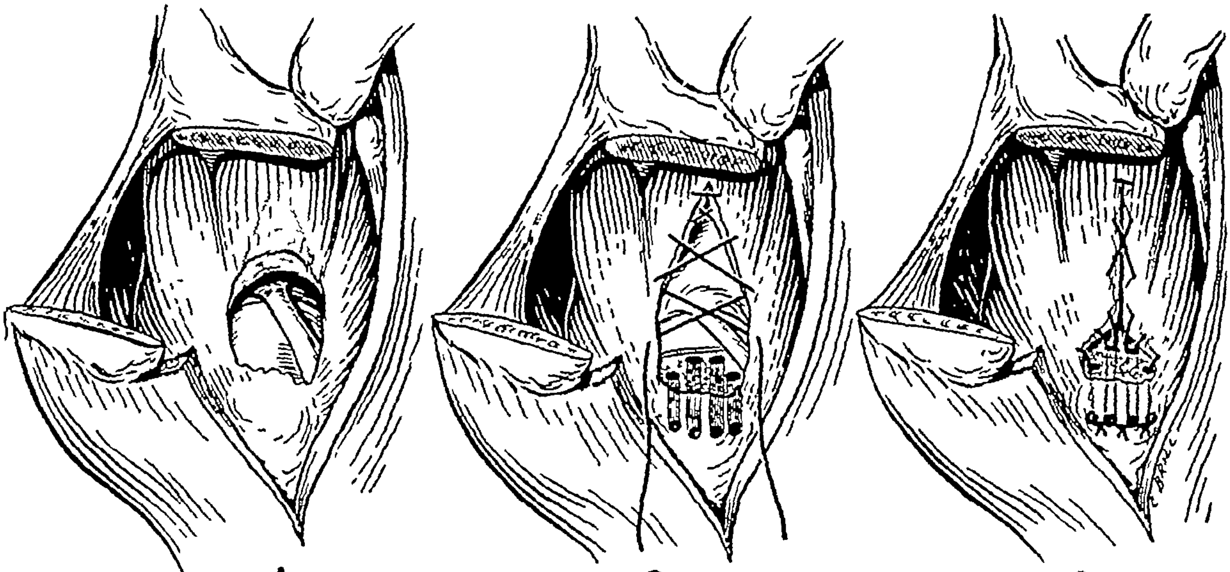
There are three types of muscle hernia congenital traumatic, and idiopathic. The traumatic type is the commonest The subcutaneous tear of a muscle fascia is due to sudden forceful contraction of the muscle The rent in the fascia can be palpated when the muscle is relaxed The muscle herniates through the tear upon contraction Operative closure of the fascial rent is rarely necessary The suture is carried out with cross stitches to achieve firmer hold of the fascial wound edges In large hernias removal of some of the protruding muscle substance is necessary before closure of the fascia can be achieved or else a dermal graft must be used (see p 42)

RUPTURE OF MUSCLES AND TENDONS

The tear of a muscle may be complete or incomplete and may involve the belly the musculotendinous junction or the tendon The lightning like severe pain followed by loss of function is characteristic. In complete ruptures a cleft can be felt which effuses after formation of a hematoma Incomplete ruptures present a diffuse painful swelling of the affected muscle The swelling is due to hemorrhagic infiltration Incomplete ruptures are treated by firmly bandaging and immobilizing the affected part for two weeks followed by massage and active motion exercise Complete ruptures require operative repair The repair of the commonest muscle ruptures will be described

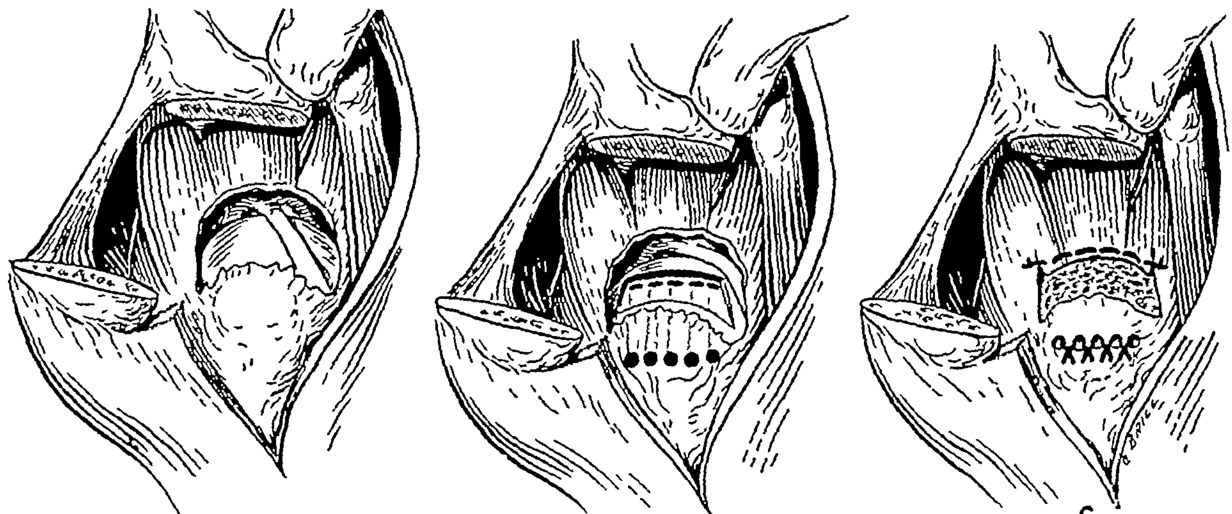
Rupture of the Rotator Cuff of the Shoulder

The so called rotator cuff of the shoulder comprises the musculus supra and infraspinatus and teres minor The musculus supraspinatus originates



A B C

Fig 319*a* Method of repair of complete ruptures (H L McLaughlin) *A* Rupture in cuff exposed through a transacromial incision, the degenerated margins of the defect are excised back into healthy tissue *B*, Shoelace type of continuous suture, beginning at the apex of the defect, is used to approximate the freshened edges of the cuff *C* The edges are approximated up to the point of tension with the arm at the side, a triangular hiatus usually remains in the cuff The articular cartilage of the head of the humerus just below the defect is removed, exposing raw bone The cuff is reattached to the humerus by passing the ends of the continuous suture through drill holes, tying them on the outer surface of the greater tuberosity, if necessary, additional mattress sutures may be added to attain better approximation of the edges of the cuff to raw bone (A F DePalma, Surgery of the Shoulder, J B Lippincott Co)



A B C

Fig 319*b* Repair of massive avulsion of the cuff with advanced retraction (H L McLaughlin) Approximation of the lateral edges of the defect may not be possible, freshened edge of the cuff is then attached to the humeral head at whatever point it reaches without tension *A* The transacromial incision adequately exposes the defect in the cuff *B* The edges of the cuff are freshened back to healthy tissue, and the articular cartilage is removed from the head of the humerus to provide a raw bony bed. *C* The cuff is reattached to the raw bony surface by mattress sutures passed through drill holes and tied in the outer surface of the greater tuberosity (A F DePalma, Surgery of the Shoulder, J B Lippincott Co)

The diagnosis of rupture of the cuff may or may not be difficult If the arm can be passively raised to a right angle but falls to the side and there is a history and local evidence of trauma it usually is not difficult to make a diagnosis of rupture of the cuff But in incomplete and chronic cases it may be difficult. In incomplete ruptures pain weakness in abducting the arm and definite active limitation of motion are the usual symptoms Acute and chronic subacromial bursitis may present similar symptoms if in doubt, the bursa should be injected with procaine If weakness and limitation of motion persist after the pain has disappeared an incomplete tear of the supraspinatus can be assumed

During the acute stage the treatment is palliative The arm should be immobilized in abduction on an airplane splint or by means of a heavy axillary pad Later the arm can be placed in a sling at regular intervals during the day however the arm should be put through a routine of gravity free pendulum exercises to prevent functional disorders If after recession of the acute stage symptoms and dysfunction persist, operative intervention is indicated McLaughlin s transacromial approach provides adequate exposure of the subacromial region. Aside from repair of the rent it may become necessary to remove the subacromial bursa due to pronounced secondary inflammatory changes. DePalma removes the bursa routinely McLaughlin devised a new way of repairing the rent. In analyzing the various forces which determine the shape of the rent he became aware that the split portion of the lesion as it extends medially becomes subject to a new mechanical force. The subscapularis pulls its anterior edge forward while the external rotators pull its posterior edge backward in this manner the typical crescentic or triangular hiatus begins to form Hence a corresponding change in the method of repair was developed Cadman s classical end to end method was changed to side to side repair and no attempt was made to restore normal anatomical reposition of the structures involved past the point of tension The diversity of the shape and size of the rent will demand alterations and modifications of this technic.

Technic (McLaughlin) (Fig 319) An incision is made to expose the shoulder joint (see page 655 Fig 352) The subacromial region is exposed through a transacromial approach The acromium is severed by oblique osteotomy of the acromium. With the tear completely exposed its degenerated and scarred edges are excised back to viable tissue The crescentic hiatus is then made into a long V shaped opening which points medially A shoelace type of continuous suture is started at the medial extremity of this opening and is placed so that traction on its ends pulls the two edges of the opening together side by side. This suture is pulled

for it When the rupture is located in the inferior biceps tendon, the motion can be done by the supinator and brachioradialis It is obvious that it is important to evaluate these possibilities before advice is given as to any surgical procedure The authors wonder whether the good results obtained after surgery are due to this compensatory mechanism rather than to the operation itself The author's case on p 986 speaks for the soundness of this argument

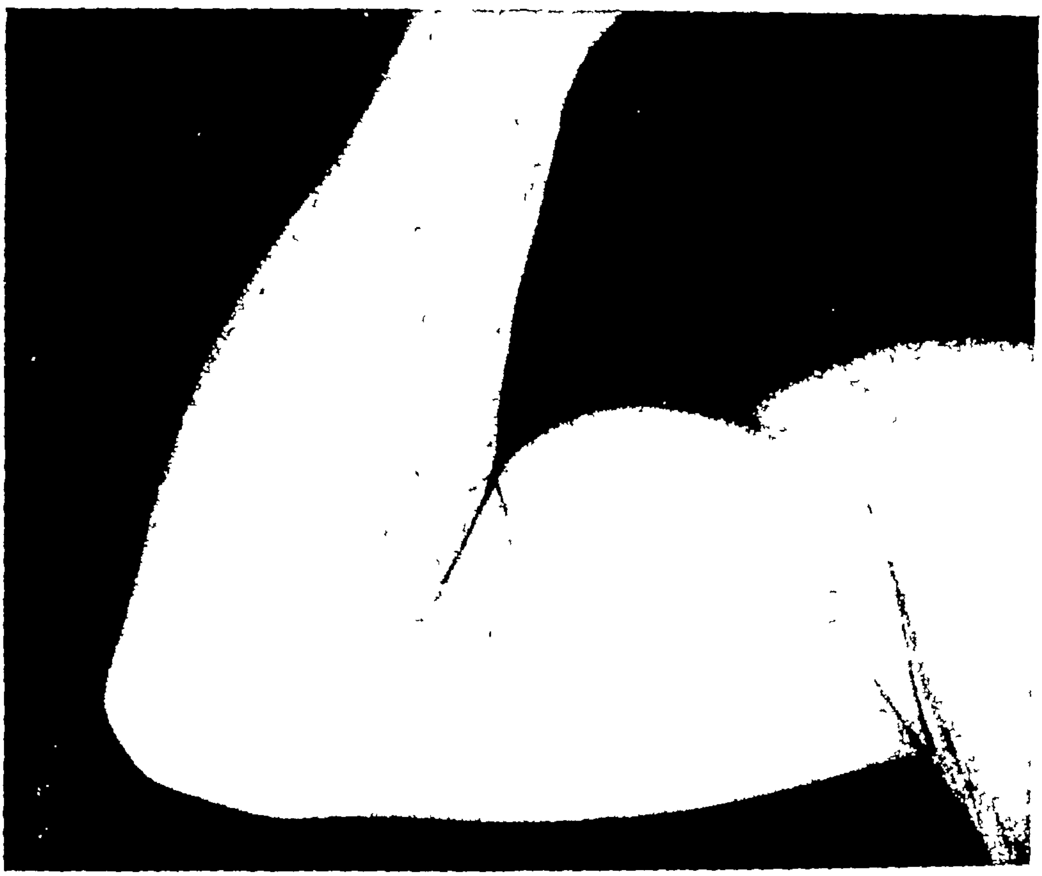


Fig 320 Rupture of tendon of long head of biceps, belly of muscle bulging in lower third of arm

Technic: An incision is made along the cephalic vein, that is, between the pectoral and the deltoid muscle. If the site of the rupture is within the capsule, it is not practical to perform intra-articular tendon suturing It is more feasible to transfer the peripheral end to the tendon of the short head of the biceps and to anchor it with a few sutures to the latter and to the coracoid process (Gilcrest) Waugh et al consider this technically quite difficult, requiring fairly large exposures (The author concurs with this) They claim to have equally good results with a simpler method consisting of suture of the biceps tendon to the insertion fibers of the musculus pectoralis major This also corresponds to the normal

snug up to but not past the point of tension When this has been accomplished it will be found that only a small V shaped opening remains The areas of the humeral head visible through this residual opening is next denuded of articular cartilage so that the edges of the opening come into contact with raw bone and two ends of the continuous sutures are passed through drill holes and are tied at the outer surface of the greater tuberosity Frequently the residual gap in the cuff is so large that the stabilization produced by the main suture is not sufficient to anchor its edges down securely to the denuded area of the humeral head when this is the case additional mattress sutures are required For repair of massive avulsions see Fig 319*b* The severed acromium is now removed. The coracoid acromial ligament is divided at its insertion into the medial edge of the acromium and as much bursal tissue as possible is removed The deltoid muscle is then sutured to the fascia and the periosteum over the remaining medial portion of the acromium and the wound is sutured in layers

After Treatment In the beginning passive movements with massage are used After two weeks the patient is allowed stooping arm swinging exercises which are increased from day to day Only after the patient is able to abduct the arm freely and strongly in a stooping position is he permitted to exercise in the erect position.

Rupture of Musculus Biceps Brachii

According to Gilcrest the rupture of the biceps muscle can occur at various places The site may be the cartilaginous attachment with the glenoid, the capsular portion of the tendon the extracapsular portion the muscular portion (usually in the middle more rarely in the upper or lower third) *the musculotendinous junction or the lower tendon* (usually at or near its insertion at the radius) In the majority of cases the rupture involves the tendon of the long head. If the rupture occurs in the tendon of the long head the belly of the muscle will be drawn toward the elbow and will bulge in the lower third of the arm (see Fig 320) If the rupture occurs through the belly and is complete a deep groove may be visible. In partial ruptures the groove is less visible. In partial ruptures conservative treatment is indicated, as outlined on p 571 The arm should be immobilized in acute flexion and fastened to the chest *with a Velpeau* dressing In complete ruptures operative repair may be necessary Roca and Vertiz propounded a sound argument. After incomplete or complete rupture of the biceps flexion and supination of the forearm can be done by the muscles of the same functional group as follows If the rupture occurs in the long head the short head and coracobrachialis which insert together in the coracoid process can substitute

wire mattress sutures McLaughlin supports these sutures by internal fixation with the removable traction suture after Bunnell. In those tears close to the superior edge of the patella, anchoring sutures through drill holes through the patella may be necessary In late cases, all cicatricial tissue must be removed before the structures are united with mattress sutures Overlapping the suture line with a dermal graft (Case 112, p 1003) is advisable to strengthen the suture and to bridge any existing gap.

After-Treatment: The extremity is immobilized in a plaster cast, from below the pubic region to the toes, for three weeks during which time quadriceps exercises are taught and encouraged At the end of that time, the cast is replaced by a shorter one, reaching from midthigh to below the calf Walking is permitted six weeks after the operation The cast is removed, and massage and active-motion exercises are instituted

Technic (Infrapatellar Ruptures): From a median S-shaped incision (Fig 359), the site of the rupture is exposed In the majority of cases, it involves the patellar or tibial insertion of the tendon, rarely the mid-portion In ruptures close to the patella, anchoring wire mattress sutures through drill holes through the patella is most satisfactory In ruptures near the insertion of the tendon at the tibia, the following procedures are recommended If the tibial tubercle is avulsed, it is returned to its original site, and fastened in place with a straight nail If the rupture is just above the insertion, a medium-sized stainless-steel wire is placed, like a mattress suture, through the tendon and through the tibia by way of a transverse canal drilled posteriorly to (beneath) the tubercle In late cases of infrapatellar rupture, the use of dermal transplants, as previously described, may become necessary

After-treatment is as in suprapatellar ruptures

In ruptures or fractures of the patella with distraction of the fragments three methods of repair are commonly employed—the indication for each should be well defined Suture of the fragments, excision of all but the largest fragment, and patellectomy After a careful analysis of a large series of cases, Reid and Rosenberg recommend suturing the patellar fragments in noncomminuted fractures through or near the middle of the patella, excision of all but the largest fragment, in fractures involving the distal one-third or less of the patella, and patellectomy for comminuted fractures or rare fractures of the upper pole

Technic (Suture of Patellar Fragments) From a longitudinal incision over the patella through skin, fascia, and bursa the fragments are exposed The hematoma between the fragment or scar tissue is removed The fragments are brought in alignment and held together either with a circumferential wire suture (the knot of it should come to lie near one

alignment of the tendon If the extra-articular part of the tendon is ruptured ordinary tenorrhaphy is performed. For locating the retacted peripheral end, exposure of the muscle beneath and below the insertion of the pectoral muscle may be necessary (see Fig 852) Ruptures at the musculotendinous junction and through the muscle itself require mattress sutures to hold the ends together If, owing to fraying or degeneration some weakness of the tissue is evident a dermal graft (p 42) should be used to reinforce the suture and to bridge any existing gap Ruptures of the lower tendon are repaired after Kerschner s method by fastening the proximal end to the radius with a nail Bjorkroth made a drill hole through the base of the radial tuberosity attached a linen thread to the ruptured tendon pulled the linen thread through the drill hole and thus pulled the tendon stump down to the tuberosity where it was secured Schmieden sutured the ruptured tendon end to the surrounding soft tissues, preferably to the anterior brachialis muscle near its insertion at the ulna

After Treatment The arm is immobilized in acute flexion and fastened to the chest with a Velpeau dressing for about two weeks Active motion is then started but heavy lifting is avoided for at least six to eight weeks.

Rupture of Musculus Quadriceps Femoris
Including Ruptures and Fractures of the Patella

The site of the rupture may be above below or through the patella Inability to extend the leg actively and the presence of a gap above the patella are typical signs of suprapatellar ruptures upward shift of the patella with inability to extend the leg, is characteristic of infrapatellar ruptures A gap within the patella with inability to extend the leg is a diagnostic sign of fracture of the patella The rupture or fracture may be complete or incomplete In either case operative repair is indicated Even in incomplete tears the operation offers quicker and better end results as aptly pointed out by Conway

Technic (Suprapatellar Ruptures) (Case 112 p. 1003) *An S-shaped* incision is made starting from the median border of the patella upward along the median boundary of the musculotendinous portion of the quadriceps for a distance well above the site of the rupture (compare with Fig 359) Skin subcutaneous tissue and fascia are severed. After exposure of the rupture it is to be determined whether the tear includes the joint capsule If the joint is entered *the next step consists* in closure of the synovial membrane Then follows closure of the rent of the quadriceps tendon or in ruptures higher up of the muscle itself with several

impossible The author has experienced this situation in two cases The gap was bridged by lengthening the quadriceps tendon, as depicted in Fig 329 and the two tendon flaps were sutured to the ligamentum patellae The results in both cases were excellent

After-Treatment In cases where tendon-lengthening has not been necessary the limb is immobilized in a short circular cast, reaching from midthigh to below the calf, for two weeks, during which time quadriceps exercises are taught and encouraged At the end of that time the cast is removed, and active-motion exercises are instituted In complicated cases with tendon-lengthening, the entire lower extremity is immobilized in a plaster cast. Cast and sutures are removed after three weeks, and a short cast is applied for three more weeks After removal of this cast, active-motion exercises are instituted. In addition, physiotherapy may be necessary.

Rupture of Tendo Calcaneus

The usual site of rupture of the tendo calcaneus (the Achilles tendon) is either at or near the insertion of the tendon at the calcaneus or at the junction of tendon and muscle. If it occurs at the point of insertion, the bone, as a rule, becomes avulsed. The most extreme case of avulsion in the author's experience is Case 114, p 1006 In ruptures of the tendon itself, the tendon generally is frayed A distinction must be made between fresh and old ruptures Immediate repair of fresh ruptures encounters less difficulties than delayed repair of old defects, since contracture of the calf muscle is not encountered in fresh ruptures

Technic: From an incision along the lateral border of the tendon, the wound edges are reflected and the site of the rupture exposed, the frayed wound edges of the tendon are excised as sparingly as possible and the tendon stumps sutured together. McLaughlin supports these sutures by internal fixation with the removable traction suture after Bunnell If the tendon is much frayed the suture should be reinforced with a dermal graft (p 42) In older cases, scar tissue may have bridged the gap, hence, the tendon may be too long This necessitates shortening of the tendon according to the method described on p 582 If it is too short the gap may be bridged according to a technic depicted in Fig 323 (Christensen), or according to Bosworth with tendon flaps taken from the raphe of the tendo-Achilles and the posterior surface of the calf muscle The author prefers bridging the gap with a dermal graft (p 42) In cases with avulsion of bone, the avulsed bone is anchored in place with a wire suture (Case 114, p 1006) The wire is passed transversely through the tendon, above the avulsed piece of bone, and then through a canal

border of the quadriceps tendon so that it can be bent and buried behind it) or a wire suture laid through parallel vertical drill holes Additional sutures through the rent in the fascia anterior lateral and mediad to the patella will strengthen the union

Technic (Suture of all but Largest Fragment) This method was originally advocated by Thompson and consisted of suturing the proximal end of the ligamentum patellae to the raw bony surface of the proximal patellar fragment. Reich and Rosenberg incorporated the tendon within the bone thus increased the opposing surface of the transfixed structures. After exposure of the patella from a longitudinal incision the small fragment is excised the remaining large fragment of the patella is grasped in a bone clamp and its raw edge smoothed with a raspatory particular attention being given to the posterior margin It is well to place a moist sponge beneath the patella to prevent bone crumbs from dropping into the joint By means of a small mastoid gouge it is possible to make a furrow in the cancellous portion of the fractured surface of the patella This furrow is about 2 5 cm (1 inch) in breadth and 0 7 cm. (about 1/8 inch) in thickness If it is made about 1 5 cm (about 1/6 inch) deep it will adequately accommodate the patellar tendon Three drill holes are made from the floor of the furrow proximally Two wire mattress sutures are placed in the tendon and threaded through these holes. The threads nearest the midline share the central drill hole and the sutures are then pulled tightly to fit the tendon snugly into the furrow The rents of the quadriceps retinaculum must be carefully repaired

Technic (Patellectomy) (Case 115 p 1004) Some surgeons have gone so far as to advocate primary removal of the patella as a routine method for recent fractures (Brooke Dood Dobbie and Ryerson and others) Others (Smillie Colin MacAusland etc.) are not so enthusiastic. It should be reserved for badly comminuted fractures and fractures of the upper pole From a slightly downward curved incision the fractured patella is exposed Additional median and lateral incisions through the tendinous expansion and the joint capsule to but not through the collateral ligaments may be necessary Removal of the fragments is facilitated by eversion of the same and dissection from the posterior surface of the tendon thus facilitating preservation of the tendinous expansions The tendinous wound edges are now approximated by mattress sutures which are firmly tied so as to imbricate the tissue and shorten the extensor mechanism The shortening of the latter is important to obtain good functional results. If besides the patella much of the overlying tendon must be removed because of destruction (osteomyelitis) or degeneration (nonunion) the defect may be so wide as to make direct approximation

owing to inward rotation (supination) of the foot and simultaneous contraction of the peroneal tendons The dislocation of the tendon of the long head of the biceps causes an audible *snap,* and is palpable on top of the shoulder joint The treatment in both instances is surgical

Technic (Peroneal Tendons): For dislocations of the peroneal tendons, Koenig recommends the formation of a fascia-periosteum-bone flap, with the pedicle at the tip of the external malleolus After replacement of the tendons, the flap is hinged downward and its peripheral end sutured to the periosteum of the lateral surface of the calcaneus

Technic (Tendon of Long Head of Biceps): For dislocation of the long biceps tendon, the most reliable procedure is intra-articular severance of the tendon and transfer of its peripheral end to the coracoid process and short biceps tendons (Gilcrest) or to the musculus pectoralis major (Waugh et al) (see p 576)

LENGTHENING OF TENDONS

Tendons are lengthened either subcutaneously or by the open method The latter is preferable in the majority of cases The open lengthening is performed in one of three ways lateral or frontal Z-method or by hinging a tendon flap

Technic (Z-Method) (Figs 321–322) The tendon is divided in its entire length either in the sagittal plane (Bayer) (Fig 321) or in the frontal plane (Fig 322) with a Z-incision After lengthening of the tendon, the tendon stumps are sutured together. The frontal lengthening has the advantage of creating two broad tendon flaps, which provide more satisfactory and firmer coaptation

Technic (Flap Method) (Fig 323, 324) Plastic lengthening of one tendon stump to bridge a tendon defect can be performed by using a flap formed in such a way that it can be hinged and connected with the other tendon stump In broad tendons (quadriceps tendon), two such flaps may be formed and hinged (Case 113, p 1004)

After-Treatment Immobilization of the extremity from three to four weeks is advisable if the Z-method has been used, from five to six weeks if the flap method has been used

SHORTENING OF TENDONS

A tendon can be shortened according to the Z-incision (see the foregoing), followed by excision of a proper-sized piece from each tendon stump and tendon suture Another way is the pleating method, in which the tendon is lifted with a single-pronged retractor. The tendon loop, so formed, is sutured together and to the tendon itself (Haas) (Fig 325)

drilled through the calcaneus beneath the site of avulsion A small incision on the median side of the calcaneus is necessary to lead the wire the proper way

After Treatment After closure of the wound the extremity is encased in a plaster cast. The foot should be in a position that will keep the suture line relaxed (equinus position) The cast remains in place for six weeks. The patient is then permitted weightbearing

Open Injuries of Tendons

The treatment of severed tendons is discussed on p 713

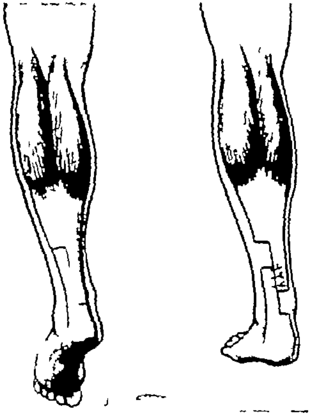


Fig 321 Lengthening of Achilles tendon. *Left:* Z-like division of tendon in sagittal plane. *Right* After lengthening and suturing.

Dysfunctions

DISLOCATION OF TENDONS

A tendon becomes dislocated after rupture of its sheath and anchoring ligaments Such an injury is rare The dislocation of the peroneal tendons and of the biceps are the only ones worth mentioning The tendon of the musculus peronaeus longus or those of both peroneal muscles can dislocate forward after rupture of their retinacula and tendon sheaths,

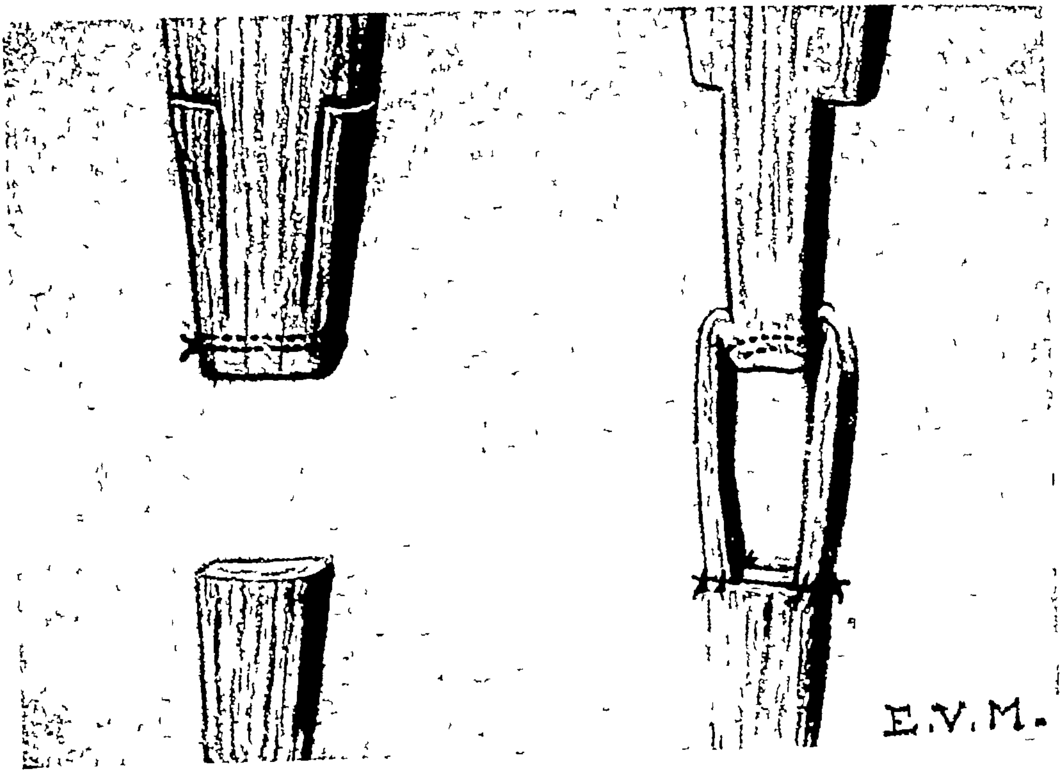


Fig 324 Lengthening of tendon by bilateral flap method
Right After hinging of flaps and suturing

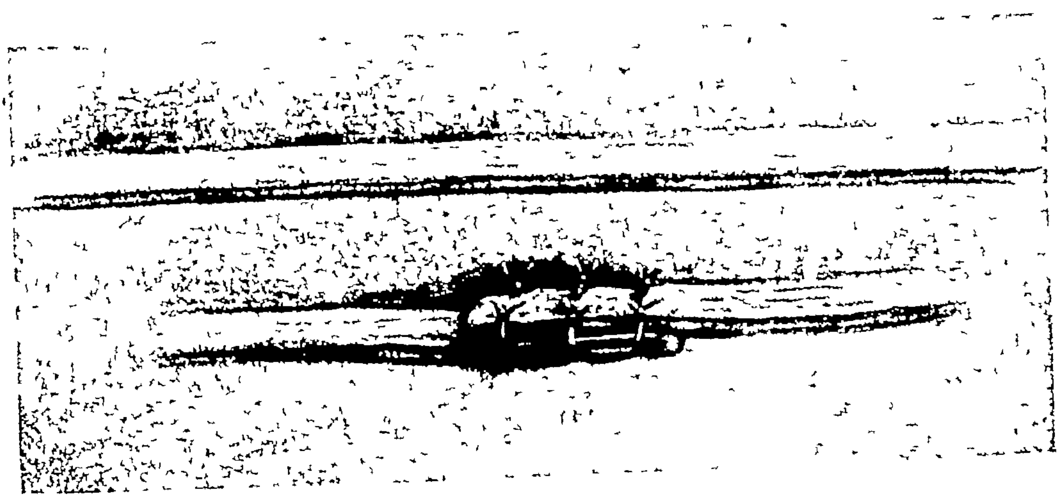


Fig 325 Shortening of tendon by pleating
Lower: After suturing tendon loop together and to tendon itself

TRANSPOSITION OF TENDONS

Tendons are transposed for the purpose of transferring the action of a functioning muscle to a paralyzed muscle The pioneer work in this field of surgery was done by Nicoladoni, Drobnik, Lange, Goldwaith, Parrish, Milliken, Codivilla, Vulpius, Biesalski, and Mayer, and others Most of these operations belong to the orthopedic field, and hence will

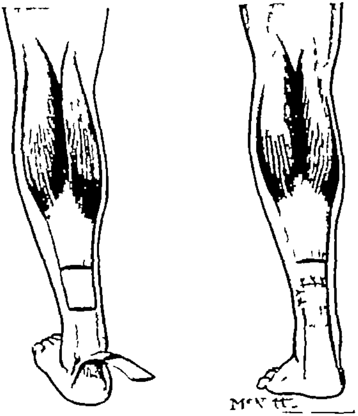


Fig. 322: Lengthening of Achilles tendon. *Left* Z-like division of tendon in frontal plane. *Right* After lengthening and suturing.

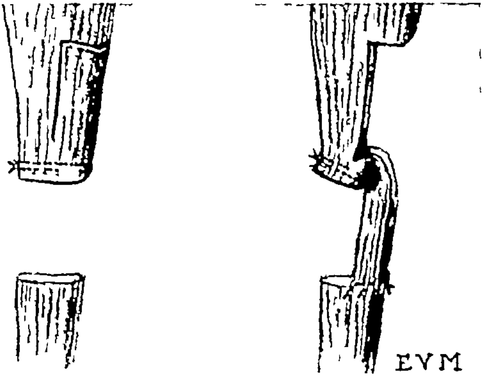


Fig. 323 Lengthening of tendon by flap method. *Right* After hinging of flap and suturing.

imbalance at its original site It should have a tendon which permits rerouting in the shortest and straightest way and which allows transfer through a tendon sheath or through tissue, with satisfactory gliding conditions It is also important that the transferred tendon be under normal physiological tension after its insertion

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not be discussed in detail (Reference is made to a recent excellent treatise of this subject by Witt.) The general principles however are outlined since the general reconstructive surgeon is occasionally confronted with these problems, such as in restoration of function after facial palsies and of the function of hand and fingers after palsies of one or more nerves of the arm

Operative Indications: These are correction of a functional imbalance of a joint caused (1) by a paralysis of one muscle or group of muscles or (2) by an overaction of muscles. In the former case (palsies due to nerve injuries and poliomyelitis), the transposition aims at the replacement of the lost function and avoidance of a deformity In the latter case (spastic paralysis), it attempts to achieve a balanced redistribution of forces by overcoming the disharmony between too much and too little.

Technic: A great number of operations have been worked out since the introduction of the method by Nicoladoni The principle of the method is to attach a functioning tendon to a paralyzed tendon. The ways of attaching the donor and receiver tendons are manifold. We distinguish between a descending and an ascending method (Vulpius) In the *descending method,* the tendon of the selected functioning muscle is severed and transferred to the paralyzed muscle. In the *ascending method,* the tendon of the paralyzed muscle is severed and transferred to the tendon of the selected functioning muscle. Hence, in the ascending method the original action of the functioning muscle is not disturbed, but some of its function is transferred to replace the paralyzed muscle. Therefore, this method has advantages over the descending method but, for technical reasons, it can rarely be employed

The descending method is more versatile It offers three possibilities. (1) The tendon of the functioning muscle is transferred and fastened to the tendon of the paralyzed muscle (Vulpius) (2) The tendon of the functioning muscle is fastened to the periosteum at or near the insertion of the tendon of the paralyzed muscle (Lange Codivilla) (3) One may use the so-called "physiological method by which the paralyzed tendon is severed near its insertion pulled out of its sheath and replaced by the functioning tendon which is inserted through the empty sheath (Biesalski and Mayer)

Any of these methods should be carefully planned and worked out A thorough electrical examination should be the first step to obtain a clear picture of the quantitative and qualitative extent of the muscle damage Proper selection of the muscle or muscles to be transferred is the next step The muscle to be transferred must have sufficient power It should be a muscle which after its transfer will not cause functional

XXIII

THE MOTOR NERVES

Open Injuries

A NERVE is severed either completely or incompletely, depending upon the type of injury If it is completely severed or its substance interrupted and replaced by scar tissue, as seen after a severe crushing injury, certain degenerative processes set in before regeneration and healing can occur Immediately after trauma, the injured nerve undergoes traumatic degeneration, which is followed two to four days later by secondary (paralytic) (Wallerian) degeneration of the entire peripheral-nerve segment Much later, the nerve becomes regenerated through complicated processes The secondary degeneration of the peripheral segment starts with disintegration of the myelin sheath which surrounds the axis cylinders (neurofibrillae) It is soon followed by degeneration of the axis cylinders themselves, which break up into fragments and granules Regenerative processes of the proximal end go hand in hand with these degenerative processes The nuclei of the neurilemma (sheath of Schwann), surrounding the myelin sheath, enlarge and multiply, forming protoplasmic bands It is still a controversy whether these cell formations actually form the axis cylinder or are only an advance protection for the newly formed neurofibrillae Nevertheless, they play an important part in the regenerative process The young neurofibrillae appear first at the central stump With the help of the advancing protoplasmic bands, they invade the peripheral segment According to one theory, they gradually grow through the entire peripheral segment, according to another, they connect themselves with less-differentiated cell groups which have formed in the peripheral segment No matter which theory is right, it is generally agreed that the Schwann cells form the all important bridge by which outgrowing axons are conducted to the peripheral stump The rate of

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to hold the sutures, while, after a few weeks' waiting, the sheath is thicker and firmer due to epineurial fibrosis Furthermore, this second operation can be carried out through incisions of election which will permit adequate mobilization of the nerve stumps and preparation for a suitable bed for the nerve These are the main arguments in favor of delayed primary repair

In civilian practice, however, in cases in which the nerve has been injured by sharp instrumentation and the wound is not infected and not badly contused, the nerve stumps do not need much resection and mobilization repair should be carried out immediately

Unless early primary repair is performed the preoperative treatment is of utmost importance The nerve injury results in a paralysis of a muscle or muscle group Unless the affected limb is properly splinted and exercised, an irreparable functional damage will result from shortening of the unprotected antagonist and eventual contracture, and from lymphedema with transformation of stagnated lymphocytes into fibroplasts which deposit collagen throughout the soft tissues Hence, the extremities should be elevated in widespread paralysis, or properly splinted in partial paralysis, and every defective joint should be put through a full range of passive motion several times daily (see also page 593, *After-treatment*)

Technic (Primary Suture): Under general anesthesia with a pneumatic tourniquet applied (see also p 716) and an electric stimulator available, the severed nerve is exposed If necessary the wound is enlarged to facilitate exposure The nerve segments should be handled with the greatest care The ends are freshened with a razor knife, not with scissors, until normal looking nerve bundles are encountered Obtaining an exact coaptation of the nerve ends is the next step, so that the corresponding fasciculi are opposite each other Small vessels visible in the epineurium in either section may be helpful in obtaining proper coaptation To avoid displacement three interrupted stay sutures are placed through the epineurium of both ends Fine silk is the best suture material and it is used on a round curved atraumatic needle Sutures with wires offer no special merit The same is true with the plasma clot suture, which is of value only in nerve grafting The wound edges to be sutured are those of the epineurium, not of the nerve substance The wound edges are everted, not inverted The sutures are interrupted and snugly approximate the nerve stumps, so that the opposing fasciculi are in close contact It is advisable to place a few radio-opaque sutures in some manner near the ends of the nerve so that a subsequent roentgenogram will yield information concerning the presence or absence of disruption of the suture

regeneration is estimated to be from 1 to 3 mm. a day For detailed information the work of Waller, Ziegler Marchand Ranvier Spielmeyer Dean Lewis Loyal Davis Kirk Gutmann Young Seddon and others may be referred to (see also Bibliography p 55) Healing of a nerve however can occur only if the regenerative processes are undisturbed If owing to infection or destruction the continuity remains disrupted or becomes so the central nerve stump becomes bulbous and forms a neuroma while the peripheral segment atrophies and undergoes fibrotic changes followed by muscle atrophy trophic skin changes and reflex disorders.

The diagnosis depends more upon the loss of motor than of sensory function The faradic and galvanic responses are also of importance, both of which gradually subside within the first twelve days and finally disappear The galvanic response however recurs in a reverse way later on (two weeks later) until the respective muscles have atrophied (reaction of degeneration) Vasomotor trophic disturbances and causalgia may also be of diagnostic value Highet introduced nerve-blocking in diagnosis of certain peripheral nerve lesions. (For detailed study among others see monographs of Groff Haymaker Seletz, Davis)

TREATMENT

In every case of open nerve injury the question arises whether to undertake primary or secondary nerve suturing Vast experience of the last war taught that the results after secondary nerve suturing were better than they are after primary repair (Sperling and Woodhall Zachary and Holmes, Seddon s unrivaled experience with nerve injuries in the British Army and others) Grantham et al however leave this question open In war wounds the local damage to the nerve ends are in the majority of cases extensive and the chances of performing adequate excision of the damaged nerve trunk and adequate epineural suturing at the primary operation were not good Hence early secondary suturing (also called delayed primary repair) was found more reliable. The nerve ends were approached only at the time of the wound excision and brought together with two stitches so placed as to prevent rotation of the stumps. The optimum time of suturing of the divided nerve was considered to be from three to four weeks after wound healing Seddon emphasizes that the nerve suture should never be performed without adequate *resection* of the stumps and without adequate mobilization of the nerve. In primary repair of a badly contused wound one will be reluctant *to embark on* wide exposure of the main nerve stump Also the all important nerve sheaths through which the sutures are laid may be too delicate and frayed

and free it from the scar tissue. Should the nerve be completely divided, the bulbous neuroma, which in the meantime has formed, is excised in thin serial sections with a razor blade The excision should be as sparing as possible in the proximal neuroma, but should be sufficient to expose normal-looking nerve substance In the distal neuroma, the resection should be more generous, if the nerve lesion was due to a severe injury, since serious intrafascicular collaginization which cannot be detected with certainty by the naked eye may be present An obstacle to the performance of a neat suture can be the retraction of the sheath after section and protrusion of the nerve bundles Seddon overcomes this difficulty by circumcision of the sheath, followed by section of the bundles at the level to which the margin of the sheath retracts The pneumatic tourniquet is now deflated and thorough hemostasis performed The tourniquet then is reinflated and remains so until the dressing is applied (see also p. 716) The nerve stumps are sutured together as already described on p 590 The nerve is then surrounded by healthy tissue or, if excision of all surrounding scar has been impossible, the scarred surface is folded on itself and obliterated by sutures The wound is sutured in layers. If the wound is near or within the flexion crease of joints, the wound should be closed at its extremities before the nerve is sutured This reduces to a minimum the awkward part of the wound suture and manipulation of the limb (Seddon).

Complications of Repair: If after resection of the neuroma a wide gap should result, which makes direct approximation of the nerve stumps impossible or insecure, the nerve should be extensively mobilized from its bed This inevitably requires separation of the nerve from the surrounding blood supply However, this separation does not endanger the viability of the proximal stump since the longitudinal blood supply is profuse, but may be harmful to the distal stump Extensive mobilization should be limited to the central stump Should this maneuver be insufficient to permit easy approximation of the stumps the course of the nerve can be shortened either by rerouting the ulnar nerve from its position behind the median condyle of the elbow joint, or by flexion of joints that lie in the path of the nerve (Naffziger, Platt, Babcock) (In rerouting the ulnar nerve the author agrees with Grantham and Pollard—The ulna nerve should not be placed beneath the detached flexor group of muscles, but the transposition should begin in the midforearm and the nerve passed through a hiatus in the deep fascia and into a subcutaneous position) The extremity is encased in a plaster cast which is replaced after three weeks by a cast that is hinged at the joint and has incorporated a screw turnbuckle. The limb is then straightened at the rate of from

line After completion of the suturing the nerve is placed into neighbor hood muscle tissue or if none is available it is surrounded by a flap or graft of fat tissue Routinely wrapping the suture line in tantalum foil (Sperling and Woodhall) has not proven of discernible advantage (Sed don Kirklin et al)

Secondary repair is carried out either as an early secondary repair in cases where the division of the nerve was diagnosed during the primary wound treatment but primary nerve suture was delayed for reasons ex plained above or as a late secondary repair where the anatomical state of the nerve had not been disclosed during the wound treatment, or if recognized repair had been delayed with the hope that spontaneous recovery would occur While in the former case suture of the nerve is carried out as soon as the wound has healed (three to four weeks after the accident) in the latter case one is justified to wait longer It is un deniable that the repair of a severed nerve is a matter of some urgency but as yet, the degree of urgency is not known Foerster drawing from his vast experience of nerve injuries, in the German army during World War I advised waiting for a period of about four to six months before exploring the injured area since such a delay appeared not to be harmful and intervention within that period might entail an unnecessary opera tion in those cases where the continuity of the nerve offered an excellent prospect of useful spontaneous recovery His experience was augmented during World War II by Zachary Seddon and others Spurling and Woodhall urge a policy of very early secondary suture (four to six weeks after the accident) Kirklin et al state that suture of a divided nerve within three months after injury gives superior results Nerves which have been sutured after three months, but not more than nine months, show a reasonable amount of recovery This experience offers a sound middle of the road advice to delay exploration about three months In the meantime physiotherapy is carried out as outlined on p 593 also revision of excessive scarring of the skin and subcutaneous tissue is per formed this may entail transplantation of a pedicled flap

Technic (Secondary Nerve Suture) Under general anesthesia with a pneumatic tourniquet applied and a nerve stimulator at hand a longi tudinal incision is made over the injured site The incision should be spiral rather than straight and bayonet over flexor region of the joints to counteract any possibility of contracture The old scar is included in the incision but excision of this scar is delayed if adherence to the underlying nerve is suspected until the nerve is explored in normal surroundings there the nerve is dissected free toward the scar It is better to dissect the scar away from the nerve than to grasp the nerve

returns after two to four weeks, function, after six weeks The final result, however, can be estimated only at a much later date—months and years after repair. If signs and symptoms of regeneration are lacking for longer than three months, the site of the lesion should be reexplored, and neurolysis should be performed (see below), with removal of any source of pressure or with resuturing of the nerve if the first suture has given way

Subcutaneous Injuries

Subcutaneous nerve injuries consist of palsies from pressure, stretching, or tearing The mildest form of pressure palsy is that from unfavorable positions of the extremities during sleep It is only transitory Palsies due to pressure of nerves during anesthesia (radial-nerve palsy from pressure of the edge of the table, plexus palsy after extreme abduction of the arm) take longer time for recovery (three months). The same is true with palsies resulting from tourniquet pressure or from dressings which are too tight Palsies from pressure caused by cicatricial tissue and callus develop gradually, and may be permanent unless released by neurolysis.

Palsies due to overstretching of the nerves (after fractures and dislocations) may be either transitory or permanent.

Palsies due to tearing are permanent, unless repaired

The diagnosis depends upon the disturbed function and the location of the lesion (see p 589)

As already discussed on p 591 the treatment of subcutaneous nerve injuries is conservative at first The injured limb is immobilized for one week and then treated with electric stimuli and massage, as already outlined If conservative measures fail to obtain results within four to six weeks, an operation is indicated, since successes with conservative methods become doubtful and the results of operative treatment less promising after this time

Exploration: The site of the suspected lesion is widely exposed The involved nerve or nerves are located and, if severed, are sutured as previously described If the nerve is not severed but found irregular in its outline, it means either that the nerve bundles are destroyed and replaced by scar tissue or that they are intact but the nerve sheath is the seat of cicatricial changes To prove the destruction or integrity of the nerve fibers, the sheath is freely opened and the nerve bundles exposed sufficiently by endoneurolysis (hersage) (see following paragraph) As a matter of fact, endoneurolysis is also indicated in cases where the nerve looks normal but definite clinical evidence of nerve interruption exists

10 to 12 degrees a week There is however a physiological limitation of overcoming nerve gaps this way as has been brought out by Highet and coworkers, Zachary Grantham et al Roughly it can be said that any suture requiring more than 90 degrees flexion of a joint may result in failure A more reliable method should then be employed i e nerve grafting (see p 55) Only rarely is one justified in resecting a piece of bone (oblique or stepladder section followed by internal fixation) unless the local condition invites such procedure (nonunion of the humerus and coexisting radial palsy)

After Treatment. The injured extremity is encased in a plaster cast or placed on another suitable splint. The paralyzed muscles should be in a position of relaxation to overcome the action of the functioning antagonists The splint should be made removable so that after the union of the nerve stumps physical and occupational therapy can be carried out otherwise prolonged immobilization would lead to stiffness of joints. Bunnell s so-called active splinting has lessened this danger (p 695) In uncomplicated cases—that is without tendon or bone injuries—physiotherapy is started on the seventh postoperative day consisting of massage and galvanic exercises of the paralyzed muscles. If it is inadvisable to remove the cast windows should be cut over the paralyzed muscles and daily galvanic stimulation applied On the fourteenth postoperative day passive motion exercises are added consisting of transient stretching of the paralyzed muscles These exercises are carried out daily after temporary removal of the splint. Between the exercises the patient is urged to move all those joints which are not necessarily immobilized Occupational therapy is added to the physical therapy Exercises are designed to reeducate the muscles to their normal coordinated function by carpeting leatherwork weaving etc. These exercises should become more vigorous with the advancement of recovery This is the time to stress synergic actions as well as dissociated movements of paralyzed muscles The splint can be discarded at this stage of recovery

Reexploration of sutured nerve should be performed if *signs of regeneration* are absent. Hence *signs of regeneration* should be discussed first. The first evidence of success is the return of sensory function this sign however may be deceptive owing to innervation from the neighborhood. The next evidence is return of the reaction of degeneration (galvanic response in reverse) and later on return of a normal response of nerve and muscles to galvanic and faradic stimuli The final evidence of success is return of active motility *in the form of feeble contraction* which gradually increases The interval between operation and return of function differs with various nerves and locations of lesions As a rule *sensitivity*

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See also Bibliography on p 79

If endoneurolysis shows the nerve bundles destroyed and replaced by scar tissue the treatment is the same as for secondary nerve suture (p 591) If the bundles are intact, neurolysis is sufficient.

Neurolysis. Neurolysis is a sort of decompression treatment. The nerve is freely exposed by dissecting all scar tissue or callus away or removing foreign bodies The epineurium is incised at the site of the lesion to relieve any tension and to reveal the condition of the nerve bundles If simple incision of the epineurium does not expose a clear picture of the situation endoneurolysis, or hersage should be added that is the nerve fibers are separated from each other by incisions in the long axis of the nerve. If the bundles are intact, the nerve is now placed into a newly prepared bed of normal soft tissue (muscle tissue or fat tissue of the neighborhood, pulled together beneath the nerve) and the wound is closed If part of the bundles are replaced by scar tissue the scar is carefully excised without injuring the normal fasciculi. After excision of the scar one may be able to suture the resected nerve ends together with preservation of the intact bundles.

The after treatment is the same as described on p 593

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the site of the injury and peripherad to it, a lateral penetration of the vessel is most likely If the murmur is also noticeable centrad to the injury, the injury must have resulted in a communicating wound of artery and vein, with the arterial blood flowing into the vein

Treatment: The treatment of vessel injuries with hemorrhages consists in emergency hemostasis, final—or definitive—hemostasis, and measures to replace the lost blood

Emergency Hemostasis This is best obtained by a pressure dressing or by correct application of a tourniquet The tourniquet may remain in place for one hour, if the emergency status is to last longer than one hour, the tourniquet should be loosened and then reapplied In regions where application of a tourniquet or pressure dressing is impossible, digital pressure against the artery centrad to the injury stops the bleeding With the second and third fingers of the left hand, upon which the thumb of the right hand is pressed, the arteria femoralis is pressed against the horizontal ramus of the pubic bone, the arteria subclavia against the first rib, the arteria carotis communis against the transverse processes of the cervical spine, the abdominal aorta with the whole fist against the lumbar vertebrae The surrounding wound is now covered with a clean emergency dressing and the extremity splinted

Final, or Definitive, Hemostasis After the patient has arrived in the operating-room, the clothing is cut away, the wound area is surgically prepared, the injured vessel or vessels are clamped with vessel clamps (see below), and the tourniquet is removed If the injured vessels cannot be found, they are located by using an anatomic surgical approach regardless of the location of the wound An exposure of the artery and vein should also be undertaken in those cases with small wounds and large hematomas The repair after removal of the hematoma is much easier and more effective than the later repair of the aneurysm which may result from such an injury

The treatment of the wound itself is done after completion of the arterial repair

The question now arises, What is the best treatment of the injured artery for the individual case, ligation or suture? Ligation used to be the method of choice Due to the great strides that have been made recently in the field of vascular surgery the suture method is more often employed, with greater benefit to the patient than was heretofore thought possible Ziperman's statistics show a decrease of the amputation rate by this method from 40 3 per cent (World War II) to 17 9 per cent (Korean war) Jahnke, Seeley, Howard, Hughes, Spencer and Grewe report similar good results, i e , achievements just short of the miraculous.

XXIV

THE BLOOD VESSELS

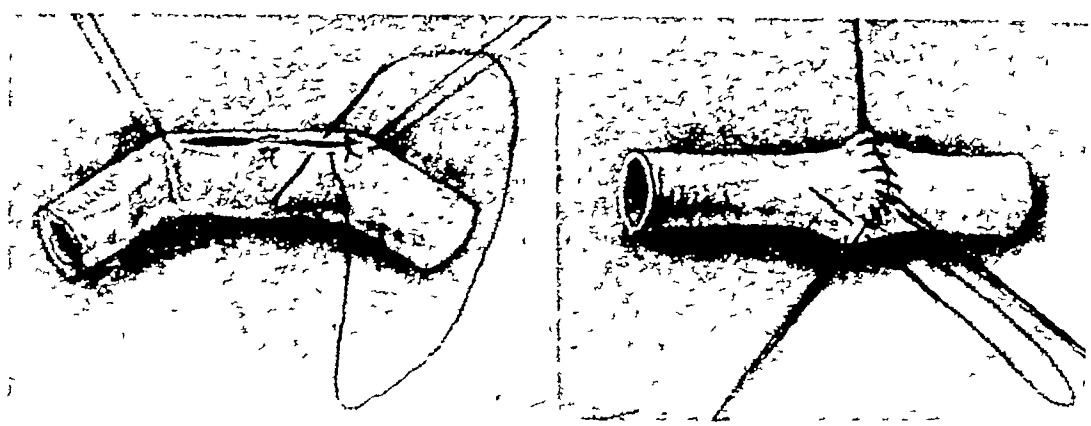
Open Injuries

Pathology, Symptoms, Signs In open injuries of the blood vessels (cut, stab or bullet wounds extensive crush injuries) the veins being attached to the fascia are more often involved than the arteries, which are more mobile and stronger and hence dodge more easily If only the outer wall of a vessel is injured—from tangential blows, for instance—such a wound heals ordinarily without consequences only in rare instances may an aneurysm develop. Penetrating wounds of the vessels however are followed by severer consequences of which hemorrhage is the most outstanding sign In case of a vein the wound may heal spontaneously under development of a thrombus, while the blood escaping from an arterial wound may bury a cavity into the surrounding hematoma (false aneurysm) If vein and artery are injured and the respective openings are in apposition an arteriovenous aneurysm may form a large hematoma may be absent owing to the suction effect of the vein

If a vessel is severed with a sharp cutting instrument the lumen gapes—that of the vein more than that of the contractile artery If a vessel is severed by blunt forces (torsion) the intima and tunica media roll in and the adventitia may elongate and thin out like a piece of glass after it is heated and pulled apart Hence a hemorrhage may be absent even if large vessels are involved.

The diagnosis of open injuries of the vessels is not difficult unless the most important sign—the hemorrhage—is absent. If large hematomas and small wounds are present, the nature of the vessel injury is difficult to diagnose If the peripheral pulse is absent a complete separation or thrombosis of the artery can be assumed If pulsation is present but less distinct than on the other side, and systolic murmurs are noticeable over

posure of the injured vessel is performed as previously described. It should be emphasized that exposure must be adequate, control of the artery above the site of the injury either by tourniquet or by temporary tape ligation through a separate incision should be considered, if for this purpose the subclavian artery must be exposed a segment of the clavicle should be removed with gigli saw (this piece of bone does not need to be replaced later on) Following the wound excision drapes, gowns, gloves, and instruments are changed, the ends of artery are clamped a few centimeters above and below the laceration with artery clamps and the tourni-



a b

Fig 326, *a* Suture of lateral wound of artery A traction suture is placed at each end A mattress suture, through all layers of wall under eversion of wound edges, is placed at middle of wound Remainder of wound is closed with continuous, everting overhand stitch

b Suture of transverse wound of artery Round circumference of vessel is changed into triangle with three traction sutures placed at equal distance through entire wall of vessel stumps In tying these sutures, vessel wall is everted so that intima comes to lie upon intima. Remainder of wound is closed with continuous, everting overhand stitch

quet is released Ligation and separation of a few of its branches may facilitate mobilization of the vessel Some of the damaged adventitia is now trimmed off This not only removes a source of infection, but provides also a sort of periarterial sympathectomy, aiding in interrupting spastic sympathetic reflexes and thus preventing arterial spasm (see p 601) Each lumen should be irrigated with saline. In suturing the vessel, Carrel's technic is generally accepted as simple and effective Nonsuture anastomosis, judging from DeBakey's experience, apparently reveals no better results, and does not shorten the operating-time Its principle consists in approximating intima to intima If the vessel is severed transversely, three traction sutures, penetrating the entire wall of the vessel stumps, are placed evenly, about 1 5 mm ($^1/_{16}$ inch) from the wound edges (Fig 326, *b*) In tying these sutures, it is important to evert the

Ligation Ligation is a simple procedure With the clamps already applied to the transversely severed ends of the vessel the vessel is pulled forward dissected free for a short distance and ligated In lateral wounds the ligature is applied above and below the wound while the part between is resected.

Ligation is the method of choice for vessels which, if ligated will not cause any serious damage or in cases of hemorrhage from larger vessels which are not controllable by other means In these cases it has been advised to ligate the accompanying vein because clinical and experimental experience has shown that this decreases the chance of gangrene as first demonstrated by V Oppel (Heidreich Brooks Johnson Kirtley and Wilson and others) The explanation is not altogether clear It seems that ligation of the accompanying vein decreases the rapidity of the venous return thus maintaining a proper balance between the arterial and venous systems The blood which flows in reduced amount through the arterial collaterals remains longer in the extremity thus providing better nutrition It also raises the tone of the smaller arteries thus stimulating collateral circulation Opinions concerning the beneficial effect of venous ligations differ however (Makins) DeBakey and Simeone Mason and Brown from vast experience with battle casualties in World War II Ziperman with those of the Korean War Cullen et al and others came to the conclusion that ligation of the concomitant vein furnishes no protection whatever against the development of gangrene after acute arterial occlusion and ligation in battle casualties

Blood Vessel Suture Suturing of vessels was introduced about 1900 (Murphy Cluck Carrel Guthrie Stich and others) (See also p 51) Its advantages however were not really appreciated until much later during World War I (Goodman Bier von Haberer and others) The recent introduction of anticoagulants sympathetic nerve block to relieve arterial spasm the use of vascular grafts and the development of special instruments such as toothed bulldog and Potts serrated clamps to control bleeding without injury to the wall of the blood vessel has added tremendously to the development of vascular surgery and to the success of the vessel suture in particular which offers the greatest hope of survival of the limb

The success of the suture depends among other factors upon the suture material Finest silk is used on fine round straight or curved needles The thread is attached to the end of the needle *the so-called* "atraumatic suture These arterial sutures are obtained from surgical supply houses They are kept in sterile oil which penetrates the silk thus facilitating smoother penetration of the suture *through the tissues* Ex

foregoing) is of advantage Others recommend injection of 2 cc of 2 per cent procaine solution into the adventitia above and below the laceration.

A thorough wound excision is now performed, the repaired vessels are well covered with soft tissue, the wound is sutured or left open to drain (p 106) The extremity is immobilized on a molded plaster-cast splint or wooden splint The position of an extremity after ligation of vessels is of importance Elevation of the extremity above the heart level accentuates the ischemia by forcing the blood flow to overcome the amount of gravity pull created by the degree of elevation above the level of the heart Hence, the extremity should be elevated at heart level or preferably in a slight dependent position (DeBakey).

A sympathetic nerve block by paravertebral injection of procaine, to counteract arterial spasm may be necessary (p 604) Anticoagulants have not been found necessary (Ziperman, Hughes, Spencer and Grewe), they may cause bleeding of the entire wound Blood and plasma expanders should be available to combat shock and to replace blood In addition antibiotic therapy is instituted

Subcutaneous Injuries and Lesions

RUPTURE OF VESSELS

Subcutaneous tears or ruptures of larger vessels occur in various forms and extent, usually from crushing or from pressure against bone or bone fragments A rapidly enlarging swelling and systolic murmurs over the injured place, as previously described in more detail, lead as a rule to a correct diagnosis The treatment is operative· application of a tourniquet, incision and removal of the hematoma, exposure of the injured vessel, followed by suture or ligation of the vessel For details of the technic, see p 598

ACUTE ARTERIAL OCCLUSION (ARTERIAL EMBOLISM)

Pathology, Symptoms, Signs: Acute arterial occlusion is ordinarily due to embolism, rarely to thrombosis The embolus originates in the left chambers of the heart or pulmonary arteries, less often in the venous system or the right chambers of the heart, crossing the septum of the heart through a patent foramen ovale (paradoxical embolism). The embolus thrown into the aorta becomes arrested either at the bifurcation of the large vessels (saddle embolus) or farther peripherad where the caliber of the artery becomes too small for its passage The preferred points are places where the arteries divide into main branches (division of arteria axillaris into arteria radialis and arteria ulnaris, of arteria femoralis into

vessel wall so that intima comes to lie on intima. If traction is now applied to these stay sutures the circumference of the vessel is changed into a triangle thus facilitating suturing and approximation The remainder of the wound is closed with a continuous overhand stitch The continuous suture commences at the site of one of the stay sutures The latter is kept under traction by the operator's left hand while the other one in front of it is held by an assistant. The suture penetrates the entire thickness of the vessel wall under eversion of the intima After one third of the suture is completed the operator takes the traction suture from the assistant, and the assistant takes the third suture after the second third is completed the operator takes the third traction suture while the assistant holds the first one The blood stream is now gradually released by opening the clamps Oozing from the stitch canals is checked by gentle pressure with moist gauze If there is still some bleeding one or two interrupted sutures will control the hemorrhage

In cases where the wound edges are under tension it is more advisable to use a mattress suture under eversion of the intima (Dorrance) (Fig 29) than to suture with a simple overhand stitch

In lateral wounds the principle of closure is the same as described that is by placing a traction suture at each end of the rent, eversion of the intima of the wound edges and their approximation by a continuous suture Eversion of the intima can be facilitated by placing a mattress suture through all layers of the vessel at the middle of the wound before starting the continuous suture (Fig 326 *a*)

In incomplete transverse wounds in which more than half of the circumference is involved it is advisable to sever the vessel completely and to perform an end-to-end suture

If the vessel wound edges cannot be united without tension or there is an actual defect of the artery and if wound conditions permit the defect should be bridged with a vein graft, which is taken from adjacent veins whose internal diameter approximates that of the injured vessel (v saphena or cephalica) or an homologous arterial graft (p 48) The concomitant vein however should not be used Plastic tubes such as Tuffier's Mustard's Hufnagel's Donovan have been used to bridge the defect, but are now superseded by flexible prostheses of plastic (orlon) fabric (p 48)

The peripheral pulse usually returns quickly In some cases there is however a slow return This is thought to be due to arterial spasm from vasoconstrictor reflexes which originate in the sympathetic nerve fibers of the adventitia at the site of the injury To relieve this spasm removal of the adventitia from the wound edges before suturing them (see the

Of the various therapeutic steps, the following are listed as the important ones.

1 Relief of arterial spasm by interrupting the vasoconstrictor impulses
2. Embolectomy or arteriectomy
3 Administration of anticoagulants.
4 Passive vascular exercise for development of an adequate collateral circulation

Interrupting Vasoconstrictor Impulses· Not only does this stimulate collateral circulation by relieving vasospasm, but it may be so effective that an operation becomes unnecessary. If an operation becomes necessary, it also counteracts the mechanical vasoconstrictor stimuli, which arise from manipulation Vasospasm should be relieved preoperatively Papaverine (0 03 gm [½ grain] intravenously), when used alone, is dubious in effect, but may be used in addition to a sympathetic nerve block, which is considered to be the most effective method of interrupting vasoconstrictor impulses.

Sympathetic Nerve Block (Leriche-Ochsner-DeBakey) Technic for Stellate-Ganglion Injection (Cervicodorsal Sympathetic Block) The patient is placed in the supine position with the head turned slightly to the opposite side A point is selected 1 cm (⅖ inch) mediad to the midpoint of the clavicle and immediately above its upper border A spinal puncture needle is then introduced inward and backward at an angle of 45 degrees with the midline, until it impinges against the anterolateral surface of the seventh cervical vertebra If no blood is aspirated, 10 cc of a 1 or 2 per cent solution of procaine is injected slowly A successful block is indicated by the rapid appearance of Horner's syndrome (mitosis, ptosis, enophthalmos of the eye of the same side)

Technic for Lumbar Sympathetic Blocks The patient is placed on the sound side in the lateral position with the vertebrae and hips flexed The lumbar spinous processes are outlined by palpation A point on the affected side two fingerbreadths lateral to the upper border of first, second, third, and fourth spinous processes is located, and procaine is injected intradermally to form a wheal and to mark the site of puncture. A spinal puncture needle is now inserted vertically at each of the cutaneous sites until the point impinges against the transverse process The needle may then be lowered or elevated and is introduced for a distance of about 5 cm (2 inches). If no blood is aspirated, 5 cc of a 1 per cent solution of procaine is injected through each of the wheals If the procedure is successful, the surface temperature of the affected side will be elevated and sweating inhibited after about twenty to thirty minutes.

arteria femoralis superficialis and arteria profunda femoris of arteria poplitea into arteria tibialis anterior and arteria tibialis posterior) Circulation becomes arrested at once peripherad to the occlusion if the embolus is small, collateral circulation has a chance to develop immediately, with the avoidance of gangrene If the clot is large it obliterates not only the main trunk but also the major part of the collateral system leading to gangrene unless removed by operation Furthermore, the presence of the embolus may cause thrombosis peripherad less often centrad, to the clot. In addition the clot induces an irritation of the endothelium of the intima, leading to spasm of the arterial system peripherad to the occlusion The intima surrounding the embolus also undergoes degenerative changes which may lead to secondary thrombosis if the first clot is removed

The history of the patient who suffers from valvular or myocardial disease is of diagnostic value The patient says he has felt a sudden severe pain in the involved extremity which was preceded by numbness Upon examination the extremity is found discolored by a dusky hue. The temperature is considerably lowered over this area and there is partial or complete anesthesia the muscles are rigid and pulsation is absent distal to the occlusion In later stages pain gradually subsides and the waxy discoloration changes into brown and finally black.

It is only natural that the site of occlusion can be assumed to be farther centrad than the discoloration suggests since collaterals central to the occlusion will supply the tissue to a certain extent The artery centrad to the occlusion can be felt pulsating It may be felt even distad to the obstruction for a short distance since pulsation may be transmitted by the clot itself

Treatment The present consensus (Key Linton DeTakats Haimovici Funck Brentano Burnett Ravdin and Wood, McClure and Harkins, Madden and others) is that embolectomy is the treatment of choice within the first fifteen hours after onset of the occlusion After fifteen hours embolectomy—as a rule—is not successful In those cases *arteriectomy* is advocated (Leriche Froment and Vachon Warren Linton et al Mc Carthy et al and others) It has been observed that gangrene is less likely to follow ligation of an artery than occlusion after embolism Hence in later stages where the intima is so damaged that thrombosis with its associated spasm and likelihood of propagation is to be expected to follow embolectomy arteriectomy at the site of the occlusion and vessel suture or bridging the defect with a vessel graft (p 48) has less chance of causing gangrene

rule, if not more than from fifteen to twenty-four hours have elapsed since the attack, embolectomy is the operation of choice The operation should be performed under local anesthesia.

Accurate localization of the embolus is essential. If pulsation is palpable up to a certain point and then stops, the site of occlusion can be assumed to be just below this point. Of supporting value is the upper level of discoloration which, as already pointed out, is always below the site of obstruction. So, for instance, if the discoloration stops at the level of the knee, the obstruction is probably in the arteria femoralis. if it reaches to midthigh and no pulsation is detectable in the femoral artery below the inguinal ligament, the embolus is to be expected in the arteria iliaca If both lower extremities are affected, a saddle embolus at the bifurcation of the aorta into both arteriae iliacae communes is probable.

The artery is exposed at the site of the suspected obstruction; that is, where pulsation ceases A thin, soft-rubber tube (catheter) is passed around the vessel above the obstruction A flexible artery clamp can be used instead, but is less easy to handle. The Bethune type of tourniquet clamp (Linton) (Fig. 327) appears to be the most versatile type The rubber tube or the tourniquet clamp is laid loosely around the artery in a simple knot, ready to be tightened by an assistant Then follows clamping of the artery distad to the obstruction to prevent the clot or parts of the clot from being carried peripherally A longitudinal arteriotomy is now performed over or slightly distad to the obstruction Unless the embolus falls out by itself, it is "milked" out or extracted with a plain forceps. The profuse hemorrhage following the release of the obstruction is stopped by elevating and tightening the rubber tube or tightening the tourniquet clamp. Sometimes the embolus is so impacted that it must be broken up with a sound or corkscrew instrument. The latter may readily be made by turning a wire in corkscrew fashion around the sound. The empty section of the artery is flushed with isotonic saline solution and the wound of the vessel wall closed, as described on p 599 The distal clamp is now removed and then the proximal clamp.

If the obstruction is proximal to the inguinal ligament and is affecting only one limb, the femoral artery is opened just below Poupart's band after placing a rubber tube loosely around the vessel above the site of the incision and clamping the artery below it A catheter, with an opening at the end and attached to a suction apparatus, is led upward toward the embolus. If suction alone does not succeed in dislodging the embolus, the clot is broken up either with a uterine sound or with a corkscrew

A continuous lumbar paravertebral sympathetic nerve block by fractional instillation with procaine which is injected through an indwelling catheter in the vicinity of the second lumbar ganglion has been described by Thomason and Moretz. Intra-arterial therapy with vasodilators such as priscoline (Lippman) is also recommended.

Embolectomy. If, sixty minutes after the nerve block, clinical findings remain unchanged—that is, an adequate collateral circulation has not developed—an operation should be performed without further delay. As a

Fig. 327: Aortic embolectomy (Linton). From right paramedian incision, bifurcation of aorta and common iliac arteries are exposed by incising and reflecting downward posterior peritoneum. Method of applying tourniquet clamps (Bethune type) is shown. They are applied in following order: First one is placed on right common iliac artery just proximal to its bifurcation, second one on left common iliac artery at distal end of embolus, third one on right common iliac artery at its origin. First two clamps are closed while third remains open until embolus has been extruded, then it is closed. Arteriotomy is between the two clamps on right common iliac artery. (R. R. Linton: Surg., Gynec. & Obst.)

next collateral The arterial ends are united with an everting mattress suture or the defect is bridged with a vessel graft (p 48)

Anticoagulants These should possibly be started during the operation. The details of administration are discussed on page 53 A word of caution, however, should be added Anticoagulants may cause bleeding of the wound In a transperitoneal approach of the aorta the bleeding may not be recognized immediately and become dangerous, in wounds it may cause hematoma Hence, routine anticoagulant treatment is not generally favored unless the subsequent occurrence of emboli is threatening

Passive Vascular Exercise Passive vascular exercise (pavaex), as popularized by Hermann and Reid, Landis and Gibbon, in the form of alternating positive and negative pressure, is used to stimulate collateral circulation It may be recommended as follows as an additional aid to conservative measures (sympathetic nerve block plus heparinization) if these have produced evidence of improvement of the collateral system, as postoperative treatment after embolectomy or arteriectomy, and as a last resort in patients seen too late for any operative treatment Burnett, Ravdin, and Wood are among others who have found the method effective

ARTERIAL ANEURYSM

Pathology, Symptoms, Signs: Arterial aneurysm is a circumscribed enlargement of an artery of congenital or acquired origin It is due either to weakness of the entire vessel wall or to bulging of certain layers herniation of the intima through a rent of the tunica media, bulging of the adventitia after destruction of the intima and tunica media (from atheromatous ulcers, for instance) This form of aneurysm is called "aneurysma verum" Another form of aneurysm is the false aneurysm, aneurysma spurium, which is caused by a laceration or rupture of an artery The blood stream, escaping from the injured vessel, burrows a cavity into the surrounding tissues The peripheral parts of this pulsating hematoma coagulate The coagulum is gradually invaded by fibrous tissue, thus a fibrous capsule is formed The artery itself is not enlarged The anatomical picture of both types of aneurysm naturally differ in many respects In a true aneurysm, the artery is enlarged, the wall is thin, endothelial lined, and slightly adherent In a false aneurysm, the arterial wall is not enlarged, the aneurysmal wall is thick, cicatricial, and adherent The clinical picture is the same In the beginning, symptoms and findings may be indistinct, later on, however, after a tumor becomes palpable and visible, a typical clinical picture develops, which is characterized by a pulsating and compressible tumor, and by crepitation with the pulsation and association of a systolic bruit and thrill All these signs disappear

instrument such as a modified Babcock vein-stripper The procedures to follow are the same as previously described

A rider embolus at the bifurcation of the aorta obstructing both lower extremities, is removed through an abdominal exposure in a way similar to that already described An improved technic (Linton) is depicted in Figs 327 328 The retrograde method from an opening in the left and right femoral arteries has also been used successfully (Hesse Ravdin and Wood) but the direct approach seems to be preferred

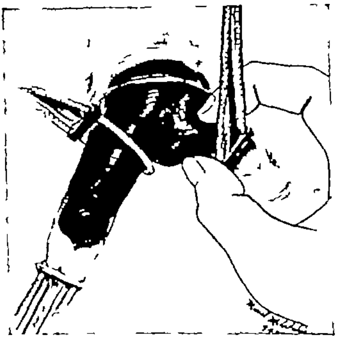


Fig. 328: Aortic embolectomy (Linton) Method of digital mobilization of embolus and its extrusion through arteriotomy in right common iliac artery (R. R. Linton Surg., Gynec. & Obst.)

After closure of the wound the extremity is immobilized on a molded plaster-cast splint or wooden splint. As far as the after treatment of the extremity itself is concerned three important points should be emphasized avoidance of all tight bandages avoidance of too high elevation of the extremity (to counteract a too early return of the blood from the veins) and avoidance of excessive heat (above 100° F)

Arteriectomy If more than from fifteen to twenty four hours have passed since the attack, the intima where the embolus is lodging is damaged to such a degree that a secondary thrombosis is to be expected after removal of the clot In these cases, arteriectomy is advisable for the reasons explained The section of the artery to be removed should include the part just proximal to the obstruction and distal but not past the

the vessel walls it may be contraindicated It is more and more becoming the method of choice in the treatment of aneurysms of the aorta (DeBakey et al.), the popliteal artery (Seeley et al), carotid artery, etc Nevertheless, these *reconstructive methods cannot* be applied or counted upon to function in every case. Hence, a sufficient collateral circulation must be assured preoperatively

Ligation of the artery above and below the aneurysm, with removal of the sac, is known as the "operation of Purmann" (1680). The operation

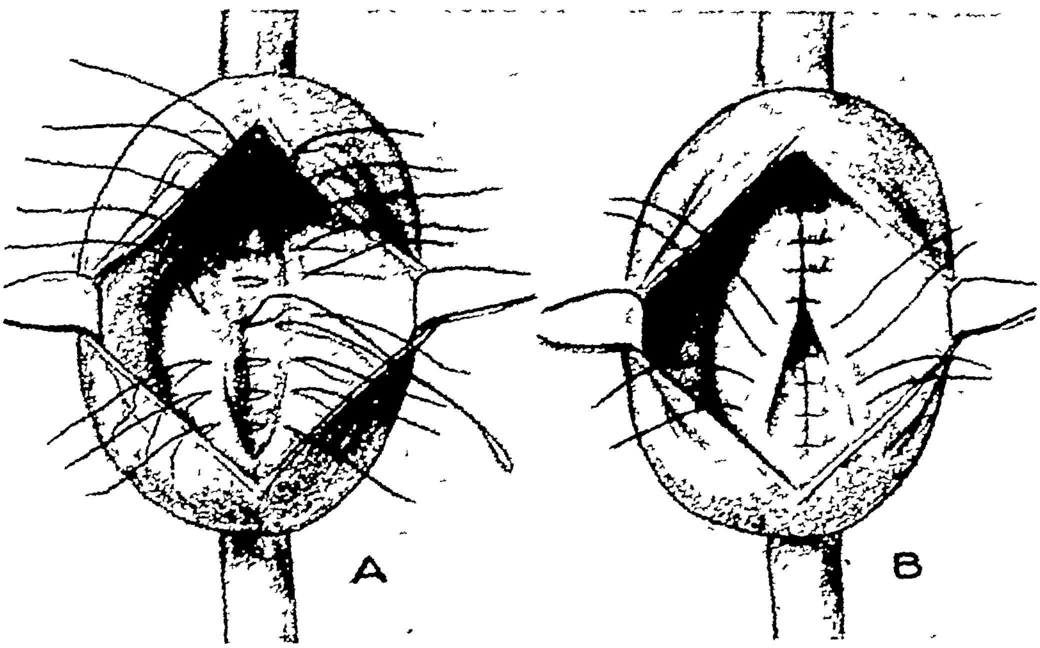


Fig 329· Obliterative endoaneurysmorrhaphy (Matas) *A* Aneurysm with two main openings in sac, both some distance apart. Obliteration of sac by rows of Lembert-type sutures obliterating space between arterial openings *B* Second row of sutures buries first one in same fashion.

is difficult, and may interfere with the neighboring structures and impair collateral circulation. Ligation of the artery above and below the aneurysm, with incision of the sac, is known as the "operation of Antyllus" (fourth century A.D or earlier). The disadvantage of this operation is the remaining sac, which has to be obliterated, ordinarily by packing Its advantage is that it does not interfere with surrounding tissues and structures or the collateral circulation. The greatest improvement in the surgery of aneurysm is the operation of Matas (1888) who, as in the operation of Antyllus, leaves the sac behind but obliterates it with a so-called "endoaneurysmorrhaphy." Matas devised three types of endoaneurysmorrhaphy: obliterative, restorative, and reconstructive; of those three methods the obliterative type is the most effective one.

OBLITERATIVE ENDOANEURYSMORRHAPHY (Fig. 329): This type is indi-

upon compression of the afferent artery The peripheral pulse as compared with the other site is weaker and delayed edema claudication neuralgia ulceration and palsies may be present.

Treatment In most instances the treatment is operative The majority of opinions favor late operation to allow formation of an adequate collateral circulation The adequacy of the latter can be tested by the Matas test which Gage describes as follows

A Martin rubber bandage is applied from the toes or fingers to a point just above the aneurysm The Matas compressor is now applied to the main artery above the rubber bandage The compressor is screwed down until the main artery is obliterated. The Martin rubber bandage is now removed. One must be absolutely certain that the compressor does not slip The foot or hand immediately after the removal of the rubber bandage has a cadaveric color The blanched toes or fingers are now carefully watched for the return of a pink color The time interval between the removal of the rubber bandage and the return of color determines the presence of an adequate or inadequate collateral circulation If the time interval is over three minutes, the collateral circulation is inadequate.

Shumacker who has considerable experience with the Mattas test considers it superior to all other preoperative methods of study He modified it slightly by producing ischemia with a sphygomanometric cuff and arterial compression by digital pressure

Development of Collateral Circulation Whenever there is some doubt of the adequacy of the collateral circulation the latter should be improved The simplest method is to delay the operation because the aneurysm itself is a powerful stimulus Passive vascular exercises (see p 608) and temporary occlusion of the afferent artery by digital pressure or the use of the Matas compressor ten to twenty minutes several times daily is efficient Sympathetic nerve block or even sympathectomy is recommended as the physiologic method (Gage and Ochsner p 604) Rarely may one have to resort to gradual occlusion of the artery by metallic bands (Halsted Matas) or by an hourglass-shaped rubber band (J C Owings)

Operation Ligation of the artery above and below the aneurysm with or without removal of the aneurysmal sac, is the classical method practiced for many centuries. The basic principles are still in vogue The so-called ideal method consisting of extirpation of the aneurysm and restoration of the continuity of the affected artery either by lateral suture or preferably direct end to-end suture (Murphy) (see Jahnke) or by bridging the defect with a vessel graft (p 48) heretofore considered only in exceptional cases, is now favored as a desirable objective It is especially applicable in young people in older people with degenerative diseases of

cated for the majority of cases particularly for those in which there are two main openings in the sac and these openings are some distance apart.

Hemostasis Circulation of the limb is controlled preferably with a tourniquet. If, owing to the situation of the aneurysm a tourniquet can not be applied vessel clamps are used

Incision From a longitudinal incision (over the joints the bayonet incision as recommended by Shumacker is advisable) the sac is exposed If a tourniquet is not used the artery leading to and from the aneurysm is dissected free and the clamps are applied. The sac is now incised with a longitudinal incision from one end to the other All blood clots are evacuated and the interior of the sac exposed by retracting the wound edges. In the fusiform type of aneurysm, two large openings are found usually at the bottom of the sac, separated by an intervening space, frequently marked by a shallow groove, which represents the continuation of the floor of the parent artery *A search should now be made for more openings derived from collaterals*

Obliteration The openings of the main artery as well as of the collaterals, are thoroughly closed with sutures. The circulation is now released to find out whether all openings have been closed. Then follows *obliteration of the sac by rows of Lembert type sutures The first row* obliterates the space between the arterial openings A second row of sutures buries the first one in the same fashion A large surface of the sac is thus brought into apposition The closing of the remaining aneurysmal space is now readily accomplished by turning the wound edges of the sac *into the interior of the cavity and tacking and holding them in contact* with the bottom and sides of the sac with mattress or simple sutures The skin is now closed without drainage

After Treatment The limb is dressed without undue pressure and immobilized. It is only slightly elevated. The patient is allowed to be up and around after from ten to fourteen days

ARTERIOVENOUS ANEURYSM

Pathology Symptoms, Signs The arteriovenous aneurysm or fistula (Hunter s aneurysma per anastomosin 1784) is a communication between an artery and a vein *In the majority of cases it is due to stab and gunshot* wounds penetrating artery and vein at opposite places (v Bramann v Bergmann Bier Makins) The communication may be intimate and if such is the case the wall of the vein opposite the fistula is bulging (aneurysmal varix) rarely the wall of the artery in other instances the arterial and venous openings may be apart from each other separated by a hematoma which gradually develops into an aneurysmal sac, thus estab-

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Treatment The operation should be performed under local anesthesia without the use of a tourniquet since the involved vessels and their collaterals are identified better when filled Quadruple ligature was the method of choice in the treatment of arteriovenous fistulae but is being gradually replaced by methods which preserve or restore the continuity

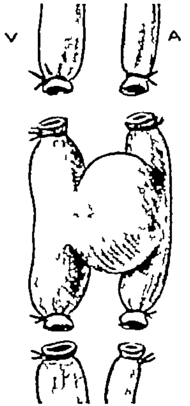

Fig. 330: Arteriovenous aneurysm. Quadruple ligation of artery and vein. Excision of involved vessels, together with fistula between ligatures.

of the affected artery (Freeman Jahnke Holman etc.) The modern immediate repair of injured vessels including potential arteriovenous fistulae as outlined in the preceding chapters has reduced the late development of arteriovenous fistulae If they do develop delayed operations consisting of restoration of arterial continuity should be the desirable objective. Excision of the damaged vessel wall and end to end anastomosis give better results than transverse and longitudinal suturing of arterial rents This excision should not be limited to the obviously damaged segment only but should include 1 cm (2/5 inch) of apparently normal vessel wall at each end of the divided artery When vessels cannot

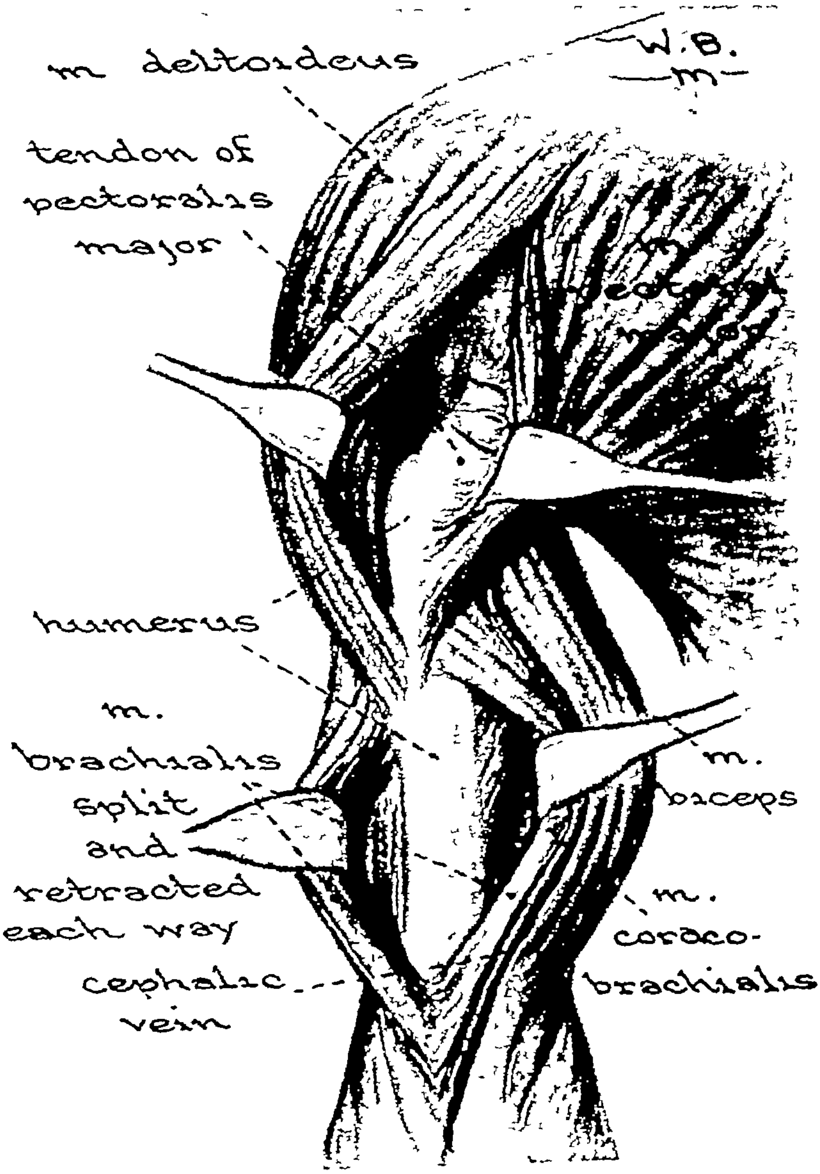

Fig 332 Anterior approach to humerus Exposure of proximal shaft between musculus deltoideus and musculus pectoralis major, exposure of distal shaft after splitting musculus brachialis.

wound to disappear beneath the lateral head of the triceps The median head of the triceps occupies the floor of the wound, by splitting it, the humerus can be exposed subperiostically The ulnar nerve being beneath the long head of the triceps may not be disturbed, neither will the brachial vessels nor the nervus medianus However, if necessary, the nervus medianus can easily be exposed in the upper part of the wound when the long head of the triceps is fully separated from the lateral head

RADIUS AND ULNA

Approach to Proximal Part of Radius and Ulna (Boyd) Figs 333-334): An incision is made along the lateral side of the distal 2.5 cm

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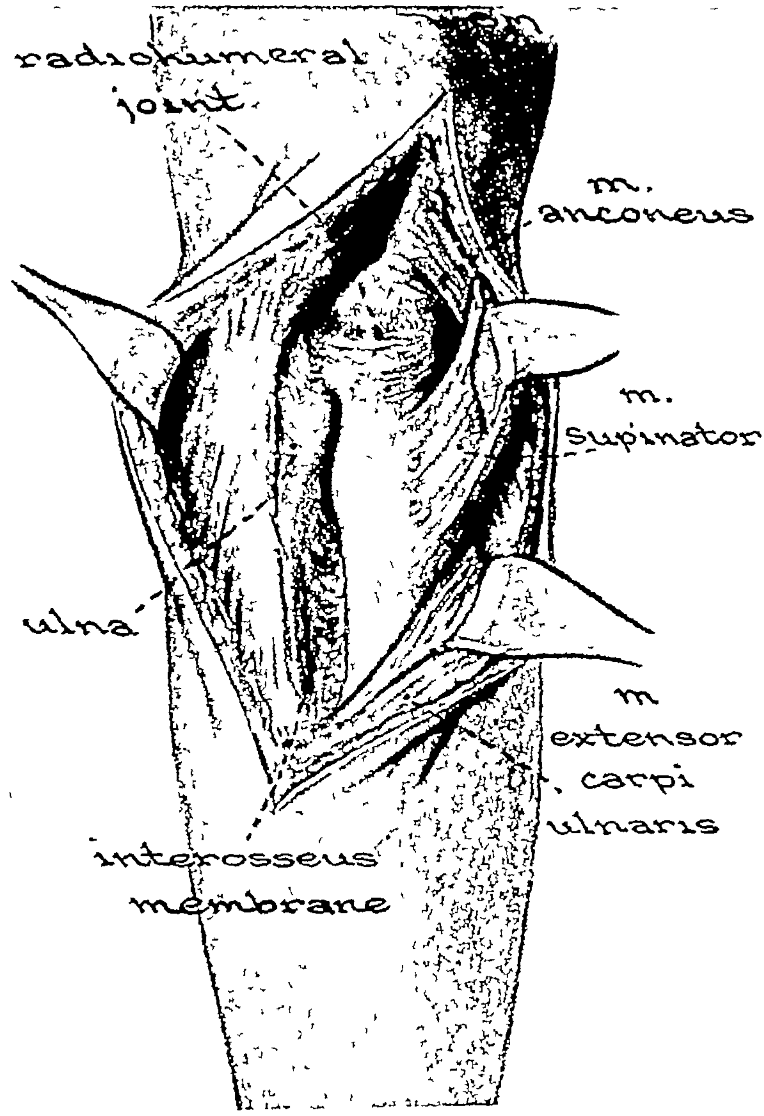


Fig 334 Exposure of proximal fourth of radius, radiohumeral joint, and lateral surface of ulna after reflection of musculus anconaeus, musculus supinator, and musculus extensor carpi ulnaris

(1 inch) of the triceps tendon and is continued distally along the lateral side of the tip of the olecranon and along the subcutaneous border of the proximal third of the ulna The insertion of the musculus anconaeus and the origin of the musculus *supinator* are severed from the ulna and stripped subperiosteally from the bone. These two muscles, together

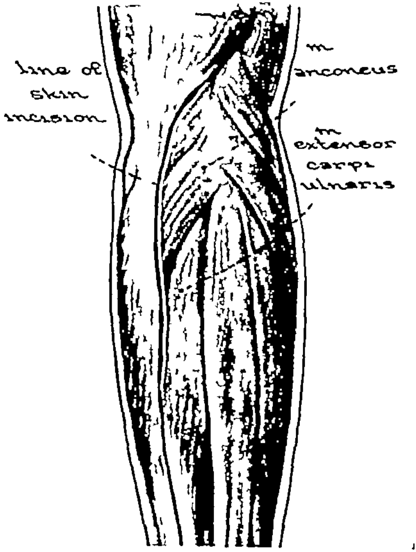


Fig. 333 Approach to proximal part of radius and ulna (Boyd) Incision along lateral side of triceps tendon, tip of olecranon, and subcutaneous border of proximal third of ulna.

with the musculus extensor carpi ulnaris are reflected laterally while dissection is carried down to the interosseous membrane Thus the head and the proximal fourth of the radius, the radiohumeral joint and the lateral surface of the ulna are exposed while the deep branch of the nervus radialis is protected in the substance of the musculus supinator

carpi radialis brevis is exposed The intermuscular septum is split, the two muscles are stripped away and retracted In the lower part of the incision, the superficial branch of the nervus radialis must be avoided It emerges from beneath the tendon of the musculus brachioradialis at the junction of the middle and lower third, and passes over toward the extensor surface of the forearm and then vertically downward It is best to expose the nerve to protect it To expose the distal third of the shaft of the radius, the tendon of the musculus abductor pollicis longus and the musculus extensor pollicis brevis are retracted toward the extensor

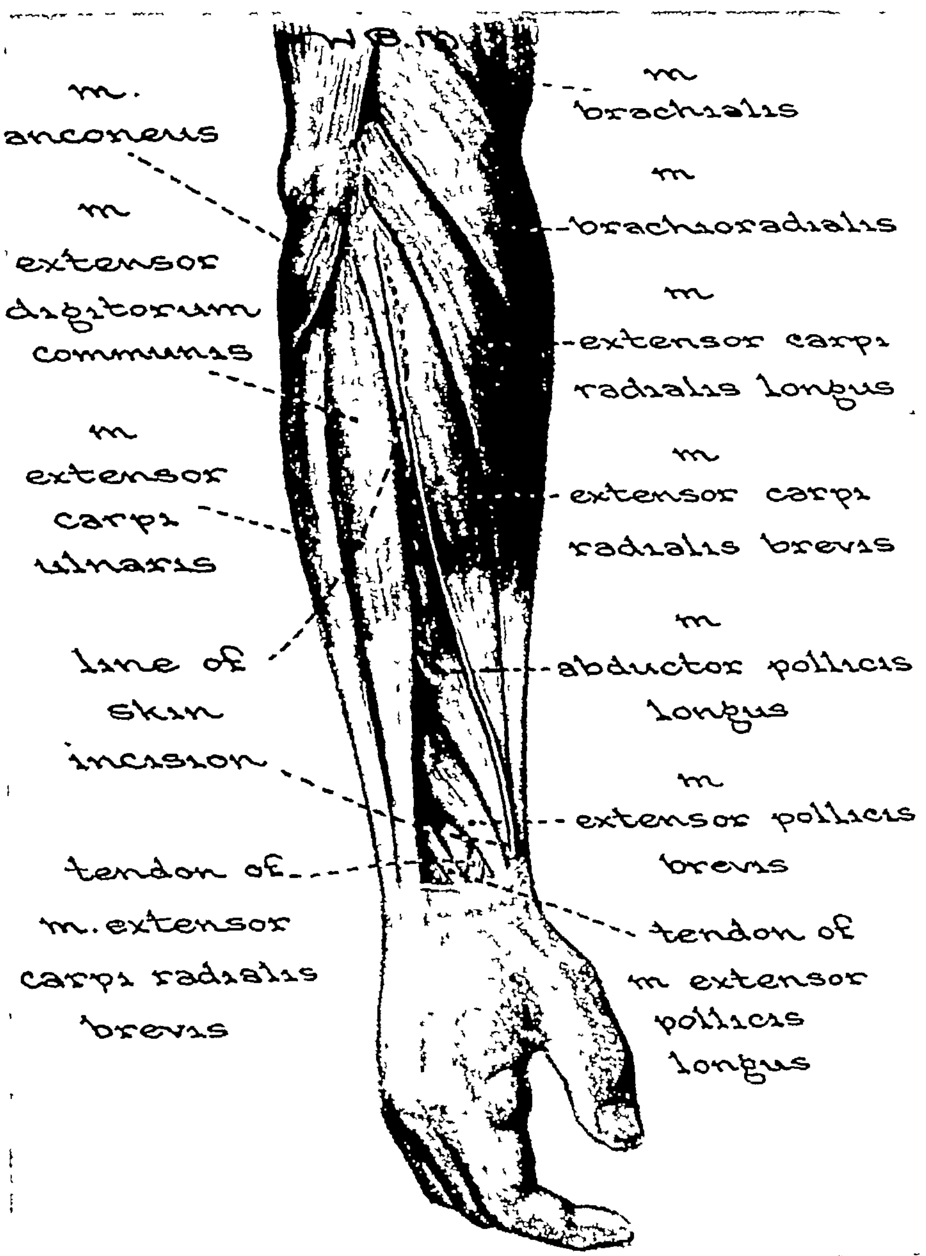


Fig 336 Approach to middle third of radius

Lateral Approach to Head and Neck of Radius and Radiohumeral Joint (Fig 335) An incision is made over the lateral surface of the lateral epicondyle of the humerus and of the head of the radius Skin and fascia are divided thus reaching the capsule of the elbow joint. The head of the radius is exposed by dividing the capsule. To expose the neck of the radius the musculus supinator is stripped from the bone. This however should be done close to the bone and not farther distally

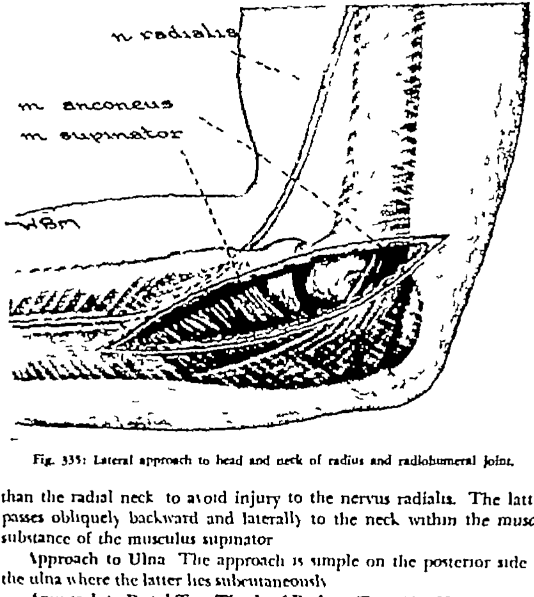


Fig. 335: Lateral approach to head and neck of radius and radiohumeral joint.

than the radial neck to avoid injury to the nervus radialis. The latter passes obliquely backward and laterally to the neck within the muscle substance of the musculus supinator

Approach to Ulna The approach is simple on the posterior side of the ulna where the latter lies subcutaneously

Approach to Distal Two Thirds of Radius (Figs 336–337) The arm is held in 90 degree flexion at the elbow joint and in midpronation An incision is made along a line connecting the lateral epicondyle with the styloid process of the radius From this incision the interval between the musculus extensor digitorum communis and the musculus extensor

if this is done, care being taken not to injure the radial vessels which lie close to this region (Darrach)

FEMUR

Anterolateral Approach to Shaft (Figs 338–339) An incision is made in the middle third of the femur along a line drawn from the anterior superior spine to the lateral border of the patella The interval between the musculus rectus femoris and the musculus vastus lateralis is exposed and the intermuscular septum incised After retraction of these muscles, the musculus vastus intermedius is incised down to the bone and reflected subperiosteally

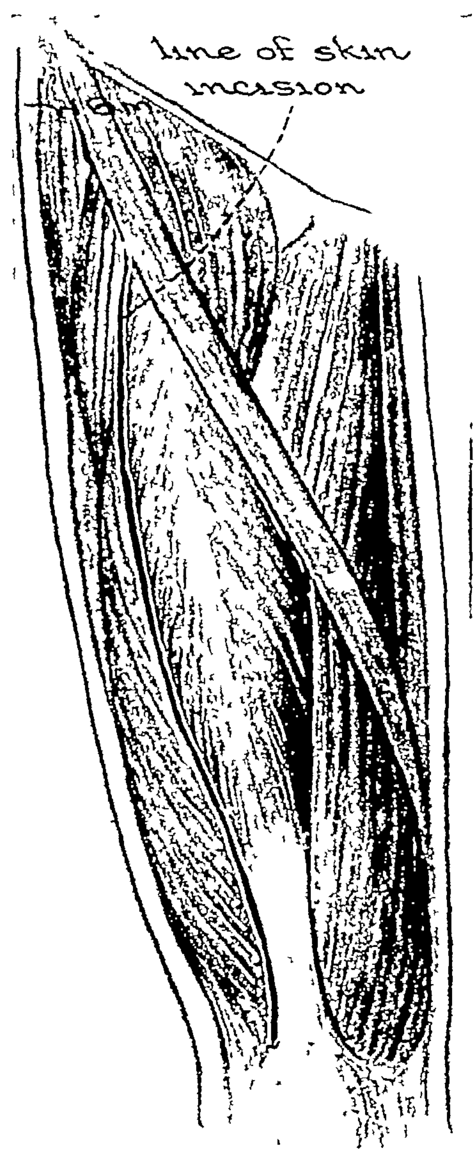


Fig 338 Anterolateral approach to femur Incision between musculus rectus femoris and musculus vastus lateralis

side of the forearm Farther distally one ought to pass between the tendon of the musculus brachioradialis and the tendons of the musculus extensor carpi radialis longus and the musculus extensor carpi radialis brevis At the epiphysis it is better to split the tendon of the musculus brachioradialis since it inserts into the base of the styloid process and reflects it with periosteum on each side A firmer closure can be obtained

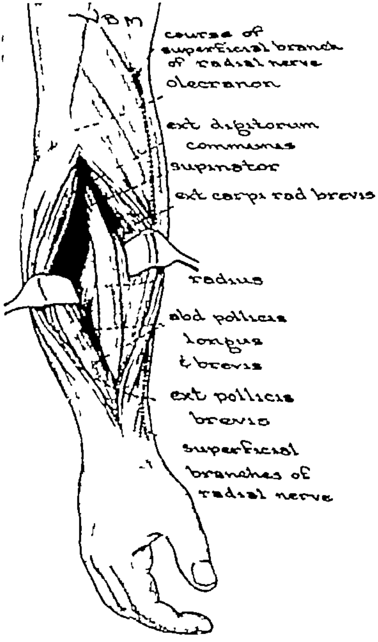


Fig. 337: Approach to radius between musculus extensor digitorum communis and musculus extensor carpi radialis longus and musculus extensor carpi radialis brevis in upper part of wound; between musculus abductor pollicis longus, musculus extensor pollicis brevis, and musculus extensor carpi radialis longus and musculus extensor carpi radialis brevis in lower part of wound.

immediately behind the iliotibial tract is divided At a point just proximal to the condyle, the biceps belly and the intermuscular septum are separated from each other Under blunt dissection, the plane of cleavage is widened and deepened Perforating vessels, felt as resistant strands, are ligated and divided Keeping close to the bone, the popliteal fossa is reached The popliteal vessels are gently mobilized and retracted backward The two great nerves, nervus tibialis and nervus peronaeus communis, are not usually seen—the former lying posterior to the vessels, the latter posterior to the short head of the biceps

Median Approach to Posterior Surface of Distal End of Femur (Henry): With the knee bent and the foot resting upon the upper part of the opposite tibia, an incision, 20 3 cm (8 inches) long, is made, starting 15 3 cm (6 inches) proximal to the adductor tubercle and ending 5 cm (2 inches) distal to it The incision follows the bend of the knee By dissecting the posterior wound edge backward, the musculus sartorius is exposed in the distal portion of the incision just proximal to the level of the adductor tubercle The muscle is freed by dividing the deep fascia along its anterior edge (care being taken not to perforate the synovial membrane of the knee, which is subjacent to the sartorius when the joint is flexed) The musculus sartorius, thus freed, falls back, exposing the *tendon of the musculus adductor magnus* The *nervus saphenus* follows the deep portion of the musculus sartorius, and must be protected The vena saphena magna is usually not seen if the skin incision has been properly placed The thin fascia immediately behind the adductor tendon is incised, and under blunt dissection the popliteal space is opened Perforating vessels may be felt as resistant strands, they are ligated and severed The popliteal vessels are gently mobilized and retracted backward; the popliteal nerves are not encountered The tendon of the musculus adductor magnus and the part of the musculus vastus medialis arising from it are retracted forward, thus exposing the bone

FIBULAS

Proximal Approach (Henry): (Figs 340–341) The skin and subcutaneous tissue and superficial fascia are incised, starting 10 2 cm (4 inches) proximal to the head of the fibula, along the biceps tendon, and continuing distally over the head of the fibula in a line toward the lateral malleolus In the upper portion of the wound, the nervus peronaeus communis is exposed where it lies close to the posterior border of the biceps tendon The nerve is freed from its path across the fibula just below the head, until it enters the musculus peronaeus longus. That

Lateral Approach An incision is made from the greater trochanter to the external condyle of the femur Skin subcutaneous tissue fasciae musculus vastus lateralis and musculus vastus intermedius are incised down to and through the periosteum. Thus the shaft of the femur can be exposed in its entire length

Lateral Approach to Posterior Surface of Distal End of Femur (Henry) With the knee slightly flexed and resting upon the knee of the other side an incision 15 8 cm (6 inches) long is made along the posterior edge of the iliotibial band about 3 8 cm (1½ inches) in front of the biceps tendon terminating at the head of the fibula The deep fascia

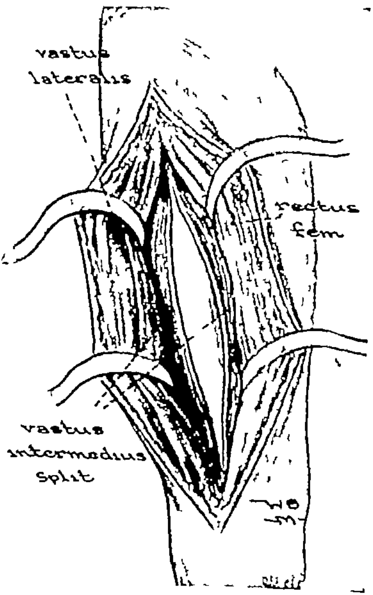


Fig. 339 Anterolateral approach to femur Exposure of shaft of femur after splitting musculus vastus intermedius.

now exposed subperiosteally. In the middle third of the fibula, one must keep close to bone with the rongeur to avoid injury to the peroneal artery. The artery runs close to the median surface of the fibula in this region

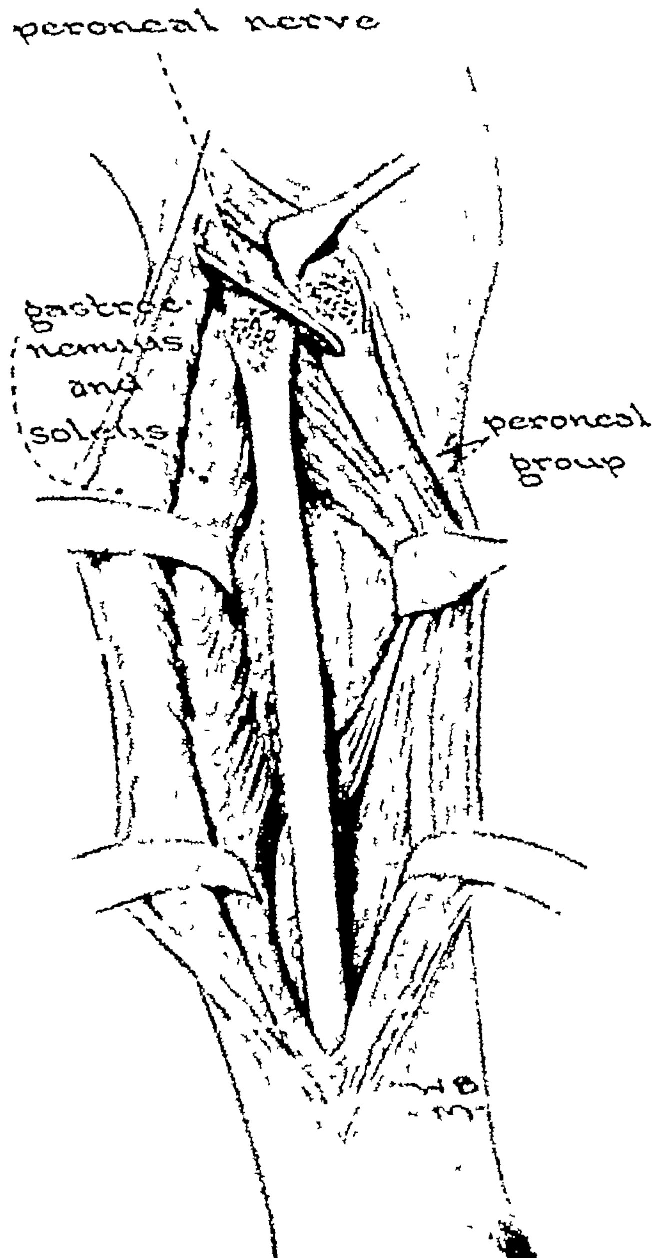


Fig. 341. Exposure of head and shaft of fibula after reflection of peroneal nerve and musculus peronaeus longus anteriorly and musculus soleus posteriorly.

TIBIA

Exposure of the tibia is not difficult, since its anterior border and anteromedian surface lie subcutaneously.

portion of the musculus peronaeus longus which arises from the lateral surface of the fibula is detached from the bone with a knife or its bony insertion is chiseled off The nerve can now be retracted across the head of the fibula The interval between the musculus soleus and musculus peronaeus longus is located and a plane of cleavage is opened between these muscles then reaching the lateral edge of the fibula. The fibula is

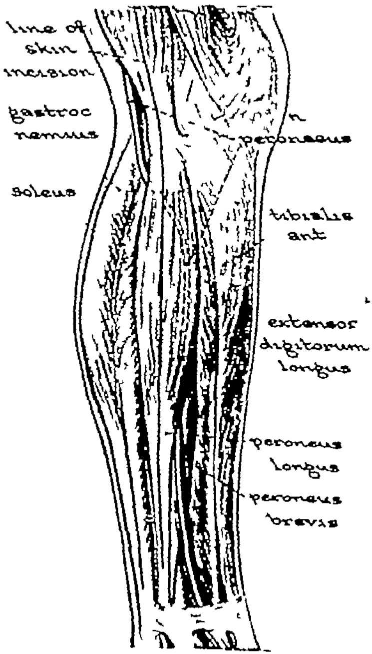


Fig. 310 Approach to fibula (Henry) Skin incision starting 10.2 cm. (4 inches) proximal to head of fibula along biceps tendon, continuing distally over head of fibula toward lateral malleolus.

a protection against fibrous erosion, but also a bone regenerative membrane.

Technic. *Exposure of Host Bone:* The operation, after the usual aseptic precautions, starts with the preparation of the host bone. The incision through the skin is curved so that the subsequent scar will not encroach upon the graft. The incision penetrates through all layers of the soft tissue, including the periosteum down to the bone. The bone itself is exposed subperiosteally by stripping the periosteal soft tissue cuff away with a periosteal elevator. In other words, it is important to leave the

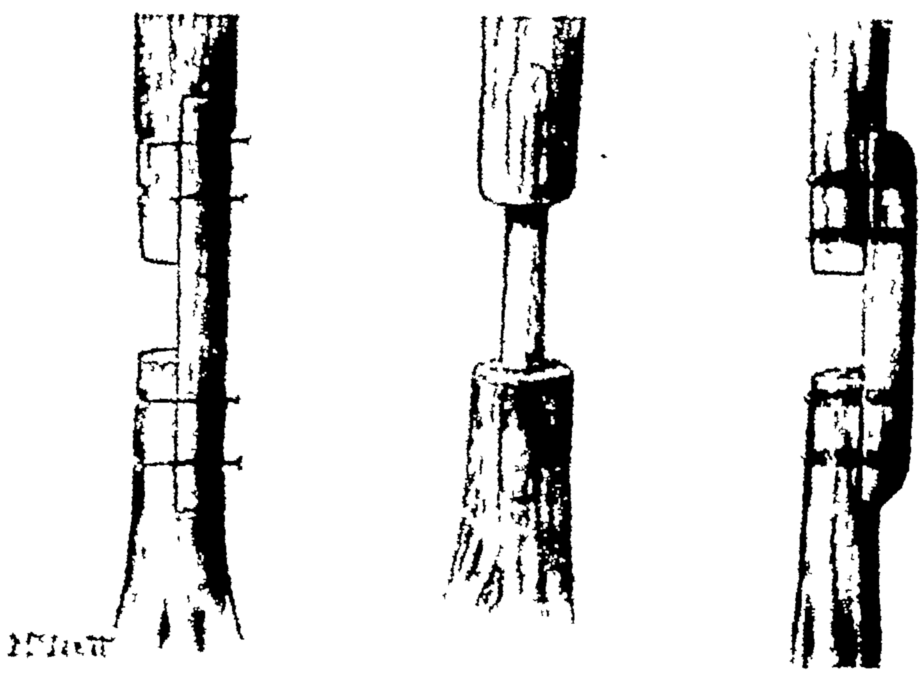


Fig. 342. Various ways of fitting and fixing bone grafts to host bone.

periosteum, if it is present, attached to the soft tissues and not to the bone, since its blood supply is mainly derived from the surrounding soft tissues. The importance of the periosteum has been previously stressed.

Preparation of Host Bone: The host bone is now prepared for reception of the graft. There are various ways to do this (see Figs. 342–344). Whenever possible the author prefers the one demonstrated in Fig. 342, *left* (Case 121, p. 1014). So, for instance, in a case of simple nonunion of a long medullated bone where the cleft is small and the bone stumps are healthy and bleeding, the outer cortex of the bone is removed in a staircase manner with an electric saw and chisels well above and below the cleft, until the medullary cavity is freely exposed (see p. 61). Exposure of the medullary cavity opens up a vascular bed, and frees the medullary osteogenetic forces—both essential factors for a quick vascularization and

Defects

Of the defects of bones, only the acquired ones will be discussed.

GENERAL DIRECTIONS

Acquired defects of bones are due to ununited fractures or to actual loss of bone from injuries (traumatic or operative) or infection In either case transplantation of bone grafts offers a good chance to bring about union. The success of the operation depends a great deal upon the local condition found and the technic used. In nonunion with a narrow cleft in which the surrounding tissues are healthy the chances of regeneration of the graft are much better than in wide defects particularly those with cicatricial changes of the surrounding soft parts.

The regeneration of a bone graft like that of any other graft depends upon the rapid reestablishment of its interrupted blood supply Hence any scar tissue surrounding the graft any hematoma separating the graft from the surrounding tissue or any infection is likely to lead to poor operative results. The second important factor in regeneration is the osteogenic forces of the host bone and of the graft itself The graft always dies, at least most of it but it becomes revivified and regenerated by ingrowth of osteoblasts derived from the host bone and periosteum less than by its own surviving osteoblasts. The osteoblasts accompany the ingrowing vessels (see p 60) Hence a broad intimate contact between graft host bone and periosteum is of utmost importance

General Rules. Needless to say the operation should not be performed in the presence of even the slightest infection As a matter of fact, if the bone defect has been due to infection (osteomyelitis) bone-grafting should be delayed for at least three months after the last fistula has closed Prophylactic use of antibiotics is also indicated in an operation in such a case

Any extensive destruction of the covering skin must be replaced by skin flaps prior to the bone-grafting operation The operator should be the only one to touch the wound the assistants hold the retractors. Thorough hemostasis is essential A tourniquet should not be applied to prevent postoperative hematomas All cicatricial tissue should be removed and replaced by healthy tissue from the surroundings. This may be difficult at times but in most instances it can be achieved by sliding muscle tissue into the defect. Sclerotic, atrophic bone ends must be removed, no matter how wide the resulting defect until bleeding bone is encountered. Whenever the periosteum of the host area is destroyed a periosteum-covered graft should be used since the periosteum is not only

the right hand. If vitallium screws are used for fixation of the graft, the graft is held in place with a bone clamp, while three holes are drilled above and below the cleft through graft and posterior cortex of the host bone The drill used for this procedure should be thinner than the selected screws The screws are then inserted through the drill holes and should be long enough to penetrate the opposite cortex of the host bone (Case 121, p 1014) After fixation of the graft, the soft tissues are sutured firmly around the graft so that they are in intimate contact with it. To facilitate closure of

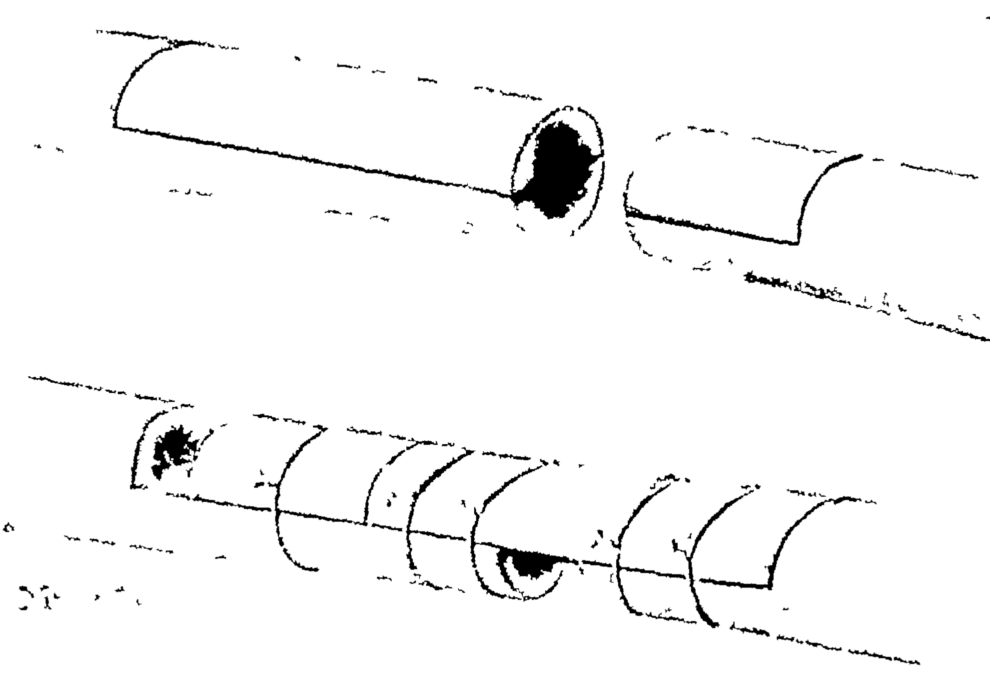


Fig 344 Sliding bone graft Main graft taken from left bone stump is slid over defect into graft bed of right stump Small graft from right stump is laid into defect from which first graft has been taken

the periosteum-soft tissue cuff it may be advisable to make longitudinal slits through the periosteum opposite the graft (Bishop et al). Then follows closure of the skin

Since the introduction of the intramedullary nail by Küntcher an excellent method of fixation may be provided for certain cases of bone grafting of the long bones Its advantage for fixation of the femur and the humerus are particularly striking D Aubigné immobilizes the extremity after such a procedure only for one month

In case of nonunion with a wide cleft or an actual defect of bone, all scar tissue between the bone stumps must be removed If the bone stumps are sclerotic and avascular, they must be resected until bleeding bone is encountered The bone stumps are now brought into alignment and prepared as described in the foregoing. To facilitate this, it

regeneration of the graft. The posterior halves of the cortex remain in place as well as the posterior part of the thin disk of scar tissue furnishing a firm connection Four wires of stainless steel to be used later on for fixation of the graft are now looped around the bone with a ligature carrier two above and two below the cleft. Fixation of the graph with screws may be preferable to wire fixation (Fig 342 *right*) The whole wound is covered with wet gauze.

Transplantation and Fixation of Graft The bone graft is now removed (from the anterior surface of the tibia for instance) (for technic see

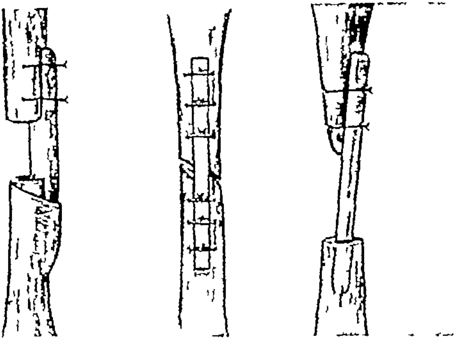


Fig. 343 Various ways of fitting and fixing bone grafts to host bone

p 62) If two operating teams are available the graft may be removed at the same time the graft bed is prepared If the periosteum of the graft bed is destroyed the tibia graft should be removed covered with its periosteum the graft should be a full thickness cortical graft in other words its posterior surface should be lined with the medullary endosteum The graft is made to fit into the graft bed with its medullary side against the medullary surface of the host bone and fastened in place by twisting the four wires firmly around it (Cases 119 120 pp 1012 1018) To prevent slipping of the wires graft and cortex are notched with a rongeur as demonstrated in the drawing (Fig 342 *left*) The wires may be twisted with a special twister but may also be firmly twisted with ordinary pliers by pushing the bone away with the thumb of the left hand while pulling and twisting the crossed wire ends at the same time with

cancellous spongy bone taken from the donor bone and scrapings or shavings from the host bone is placed about the site of the cleft and the margins of contact between bone graft and fragments

Inlay Graft (Albee) The principle is outlined in Fig 343, *center.* With a twin-bladed, circular motor saw, a full-thickness piece of cortex of sufficient size is removed from above and below the cleft. Holes are drilled through the cortex along the gutter and small kangaroo tendons threaded through them. A slightly wider, but otherwise identically shaped graft, corresponding in length to the entire length of the gutter, is removed from the tibia and driven into and fastened firmly to the gutter by tying the kangaroo tendons Instead of kangaroo tendon, vitallium screws may be used, as previously mentioned.

Sliding Graft· In suitable cases—mostly the tibia when the cleft is small and the adjacent bone stump healthy, vascular, and of sufficient length—a sliding inlay graft (Albee) or massive sliding graft (Gill) can be used (see Fig. 344, Case 120, p 1013).

Bone-Pegging. This has been a popular method, popular because of its simplicity (see Fig 342, *center,* and Fig 343, *right*) The destruction of medullary tissue, resulting from driving the peg into the medullary cavity, has often caused failures Hence, a bone peg should be used only in exceptional cases; that is, in regions where the peg is driven through cancellous bone and not through the medullary cavity; for instance, in bridging nonunions of the neck of the femur (Cases 116, 117, pp 1009, 1010), of the naviculare of the wrist (Case 158, p 1063), of the internal malleolus (Case 122, p 1015), of the head of the humerus (Case 115, p 1008), of the upper condyle of the tibia.

Interposition of Cancellous Bone Blocks Nicoll advocates the use of a solid block of cancellous bone which is interposed between the ends of the host fragments and must be tight fitting It is held in this position by internal fixation with a metal plate

Bone Chips See p 66

While the technic of bone-grafting for nonunions and bone defects does not differ among the long medullated bones, there are certain types of defects in certain regions which deserve special description.

HUMERUS

Proximal Third of Shaft Case 115, p 1008, see also p 674) · The humerus is exposed from an incision as outlined in Figs 331–332 To free the bone, it may become necessary to sever the insertion of the musculis pectoralis major and other muscles This should be *done close to the bone* The bone is freed subperiosteally, and the resection, for tumor or cyst forma-

may become necessary to lift the bone stumps out of the wound with a special bone clamp This can be done to a certain extent without disturbing the circulation of the bone since each bone stump ordinarily has a well-developed collateral circulation through the epiphyseal and metaphyseal vessels The adjustment and fixation of the full thickness cortical graft is the same as previously described (Case 115 p 1008)

After Treatment The extremity is immobilized in an unpadded split plaster cast. The immobilization must be complete hence the cast must include the joints proximal and distal to the grafted bone The place from which the graft was taken is sutured and is dressed in such a way that the dead space at the site of removal is obliterated by placing a longitudinally folded compress of gauze upon the skin over the donor area. Then follows a dressing pad moderate pressure is applied by a circular bandage If a thick graft was taken the donor leg should be encased in an unpadded plaster cast for four weeks. If the tibia unfortunately should have been fractured during the removal of the graft, the leg should remain immobilized for eight weeks

A bone graft passes through three phases before it becomes an organic unit (see p 60) (1) the stage during which the graft is dead (2) the stage of transformation into living tissue (the osseous tissue condenses, the surface becomes smooth and organic fusion occurs between graft and host bone) (3) the stage of functional adaptation in form and increased strength of the graft to its mechanical requirements whereby the graft becomes thinner or thicker according to the functional demand Hence the important principle of the after treatment is absolute immobilization of the grafted limb during the first and second stages of regeneration that is from two to five months. It is during those stages that the graft has the least resistance not only to rough handling but also to minor influences especially when the latter are ever present. Therefore fractures or formation of fissures are the consequence of too-early mobilization. Thus, the grafted limb must remain immobilized until the roentgenogram shows good fusion between graft and host bone If *infection* should occur the graft need not be removed immediately for it may happen that in spite of pus formation the entire graft or parts of it heal

Alternative Methods. *Massive Onlay Graft (Henderson Campbell)* The principle is demonstrated in Fig 512 *right* The medullary cavity is not opened The anterior rounded surface of the cortices above and below the cleft are shaved off with a chisel until a flat surface is created a full thickness cortical graft from the tibia is removed and placed with its medullary side against the prepared surface of the cortices It is held in place with a bone clamp and fastened with vitallium screws In addition

This instrument is a pie-shaped sector made of aluminum, which is faintly opaque to x-rays (Fig. 345). On this sector are converging lines of a metal which is densely opaque to x-rays, converging at the apex of the sector. Underlying each of these lines are two square canals, one canal being just under the other (Fig. 345, *insert*). Into these canals will fit square steel pins, constructed with a tapering sharp point at one end and

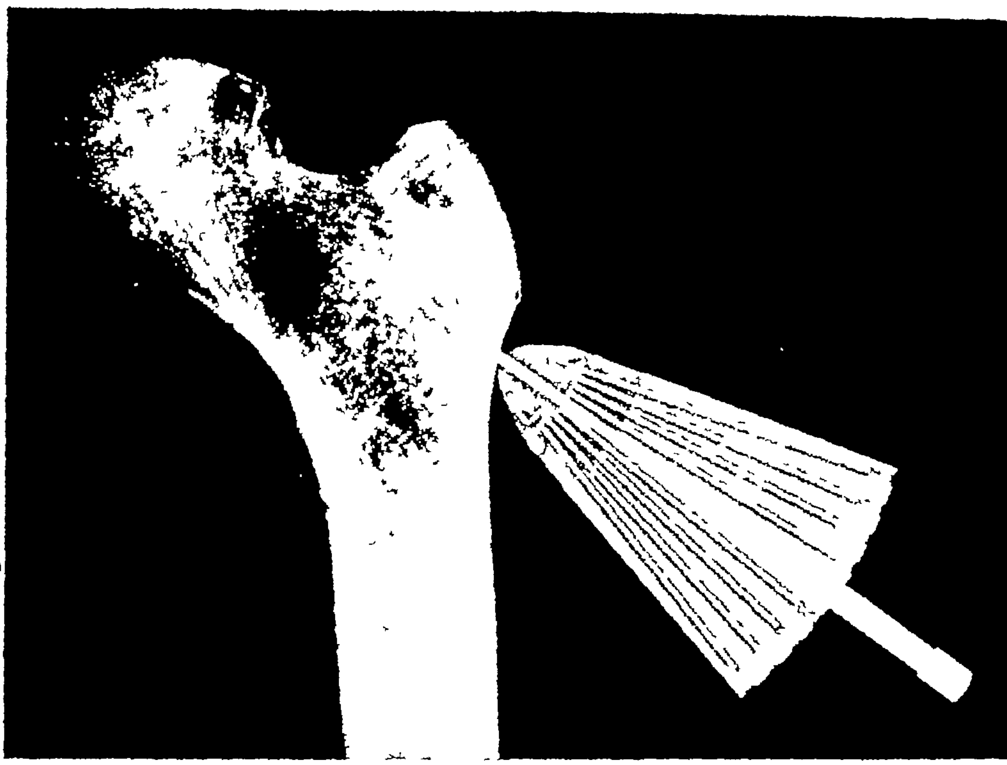


Fig 346· Direction-finder held in place by holding pin
(G. C Engel and H May J A M A)

a screw thread tapped at the other. There is a cap which screws on the end of the pins The purpose of this cap is (1) to take the blow of the hammer when the pin is driven into the cortex, (2) to hold the plate snugly against the femur, and (3) to withdraw the pin from the cortex of the femur by screwing up on the cap. All these canals take a 3/32-gauge Kirschner wire.

Insertion of Guide Wire. An incision is made from the great trochanter, 5 cm. (2 inches) in length or longer, paralleling the shaft of the femur. This incision is carried down through the periosteum to the bone. The two-plane direction-finder is then inserted into the incision so that the apex bisects the angle formed by the great trochanter and the shaft of the femur. The square pin is inserted into the center hole of the lower row of canals, the cap being partly screwed on, and is driven

tion for instance is carried out with a gigli saw distally through the shaft and proximally close to the head of the humerus. To bridge the defect, a fibular graft is selected and removed subperiosteally or covered with its periosteum depending upon the condition of the host periosteum (for technic, see p 65) To fasten the graft to the distal bone stump the latter is prepared as previously described To fasten the graft to the head of the humerus a canal is chiseled or drilled through the longitudinal axis of the head of the humerus close to but not through the articular surface. The tunnel should be made slightly smaller than the circumference of the fibula The graft is now pegged into the bone That particular part of the graft which comes to lie within the head of the humerus should be free of periosteum. The lower part of the graft is now fastened to the distal bone stump as described in the foregoing Here again that part of the graft which comes in contact with the bone should be free of periosteum Instead of a fibular graft, a large tibial graft with a pointed end may be used.

The soft tissue cuff is now sutured snugly around the bone The arm must be immobilized in a cast which includes chest and arm as well as the middle portion of the hand with the arm in 90-degree abduction and slightly forward position at the shoulder and 90 degrees at the elbow joint The forearm should be midway between pronation and supination The author has found it convenient and expedient to apply the chest part of the cast preoperatively This part includes a piece of felt from below the crest of the ilium and along the lateral chest wall lining the axilla of the involved arm It is held away until used after the operation

Distal Third of Humerus An incision and procedure similar to those in the foregoing are used For better fixation, however it is advisable to leave a posterior or lateral shell of bone attached to the distal or condylar bone stump so that the graft can be pegged into the condyles and also fastened with a wire loop Immobilization is similar to that described previously The Küntscher intramedullary nail fixation (p 634) may also be available

ULNA AND RADIUS

Proximal Third of Ulna The ulna is exposed from a posterolateral incision (Fig 333) The bone stumps are prepared in the usual way a tibial graft is removed and fastened in place. In this region however it is safer to fasten the graft with screws and not with wire loops so as not to endanger the radial nerve

Middle Third of Ulna or Radius (Case 121 p 1014) This is a favored region for nonunions The technic does not differ from that described on p 632 The incision for the radius is outlined in Figs 336–337 The

axis of the neck of the femur in this view Through its corresponding inserted a Kirschner wire (Fig 348) This wire has previously been marked (see following paragraph) so that when the mark on the wire reaches the outer edge of the direction-finder one knows that the point of the wire is just to the head After the wire is in, the direction-finder and its holding pin are both withdrawn

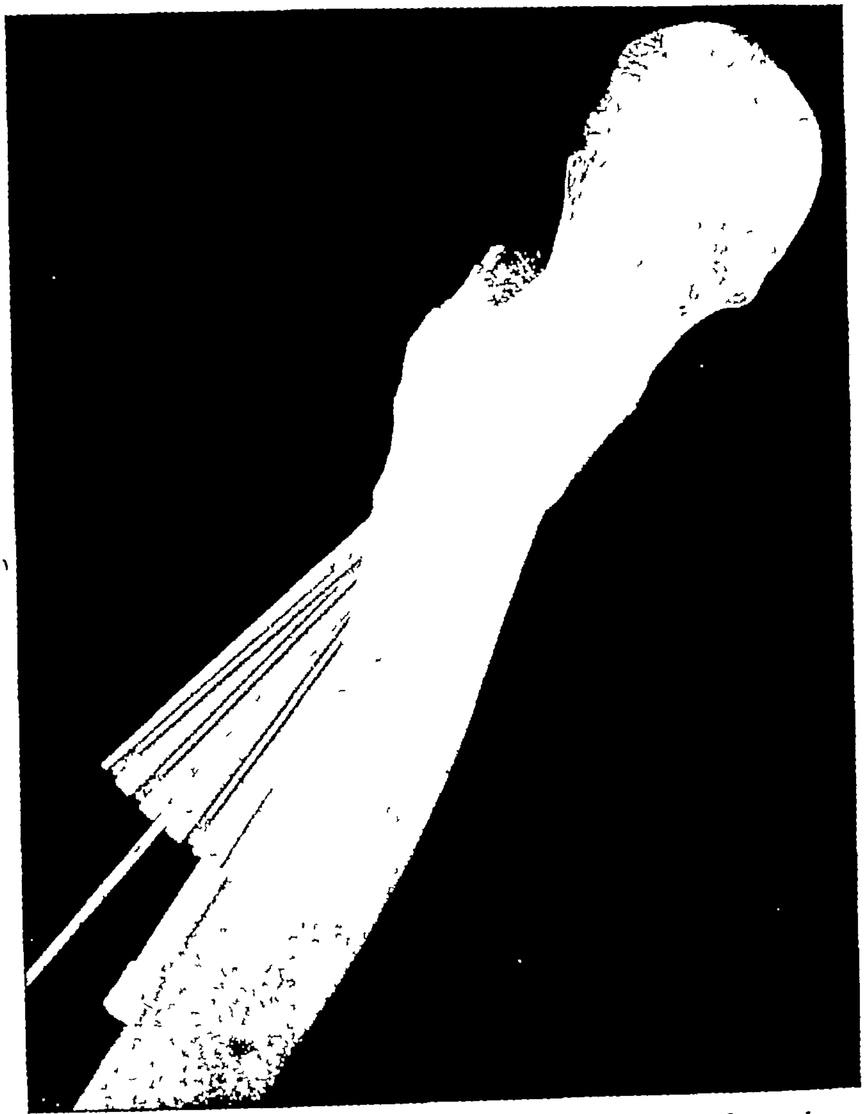


Fig 348 First pin is removed Direction-finder is removed, turned at right angles, and slid over second pin Lateral x-ray picture is taken (see Fig 349) Again, converging line is selected which is in long axis of femur A Kirschner wire is drilled through corresponding canal in opposite row to which pin is inserted Proper length of wire is determined from formula of Fig 350 (G C Engel and H May J A M A)

Deduction of Measurements· Knowing the actual length of the direction-finder, which is 9 cm (3½ inches), the actual length of the neck of the femur is found by a simple calculation in proportion The actual length of the direction-finder is to the length of the direction-finder, as

into the cortex of the bone. The plane of the direction finder is parallel to the long axis of the femur (Fig 346)

An anteroposterior roentgenogram is then taken and the converging line in the x ray plate which is in the direction of the long axis of the neck of the femur is selected Through the corresponding tube is inserted a second square pin in the opposite row of holes to which the first pin was inserted (Fig 347) The first pin is then removed by setting up on

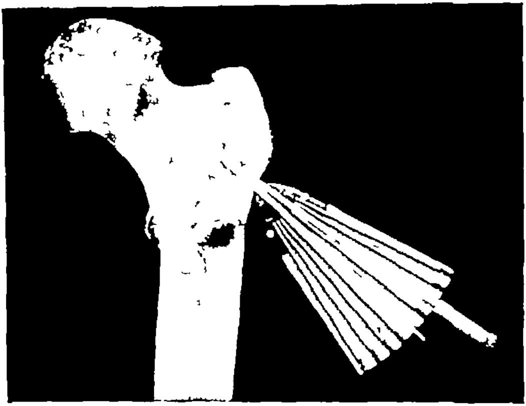
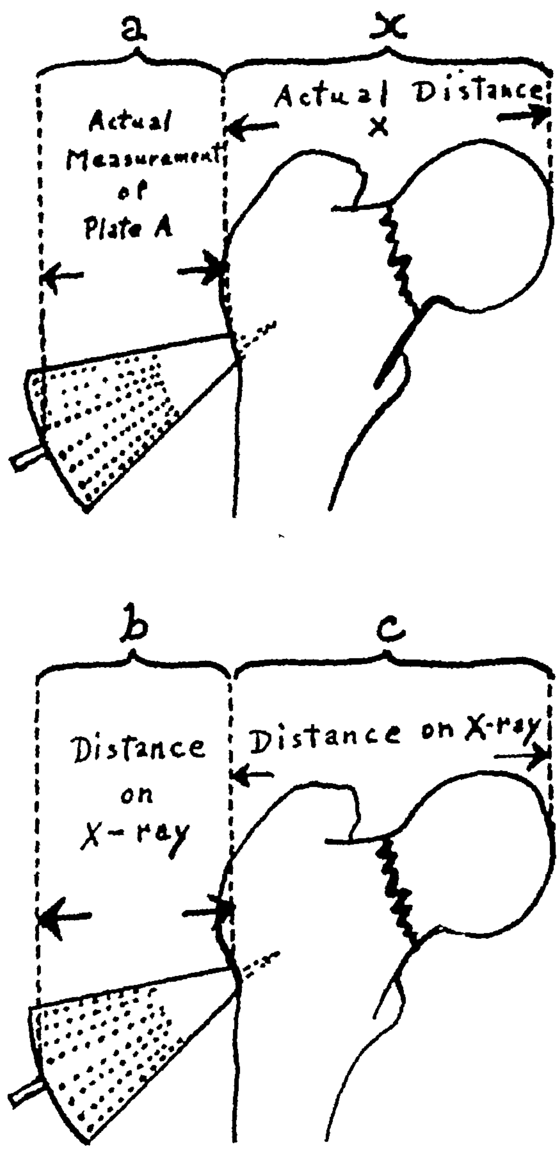


Fig. 347 From anteroposterior x-ray picture, converging line, which is in long axis of neck of femur is selected. Second pin is inserted through corresponding canal in opposite row of canals to which first pin was inserted. (G C. Engel and H. May: J A. M. A.)

the thumbscrew cap leaving only the second pin and the direction finder in position The direction finder is then slid off the second inserted pin turned at right angles and inserted over the pin again the pin passing through the center line of the upper row of canals. The screwcap is screwed snugly on this pin to keep the plate in position A lateral x ray view is then taken by pointing the cone of the x ray tube under the unaffected leg the thigh of this leg being flexed on the trunk so that the cone of the x ray tube is perpendicular to the plane of the direction finder and perpendicular to the x ray plate which is held parallel to the plane of the direction finder and just above it (Fig. 349) From this lateral view again the converging line is selected which is in the long

of the head of the fibula should be well padded so that the patient, after incorporation of a walking-iron, can be up and around on crutches. The cast is removed after three months. If the checkup x-ray picture reveals union, the patient is allowed weightbearing; otherwise he walks on crutches until there is evidence of union (Cases 116, 117, pp 1009, 1010). If it is possible to insert a Smith-Petersen nail, in addition to the graft, or to apply any other means of intramedullary fixation, plaster cast immobilization can be avoided.



$$\frac{a}{b} = \frac{x}{c}$$

Fig 350 Deduction of measurements How to determine exact length of neck of femur (G. C Engel and H. May J A M A)

measured on the anteroposterior x ray plate as x (the actual length of the neck of the femur) is to the measured length of the neck of the femur in the x ray plate. Thus, the actual length of the neck of the femur is determined (Fig 350) By adding the actual length of the neck of the femur to the actual length of the direction finder, one gets the length which is marked on the Kirschner wire. The actual length of the neck of the femur minus 1.2 cm. (½ inch) gives the length of the bone graft.

Final Checkup on Wire To be sure that the wire has the proper direction and length a final anteroposterior and lateral x ray picture is taken After this checkup the wire is drilled 3 cm (1³⁄₁₆ inches) deeper

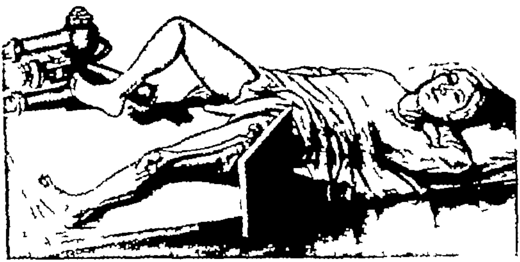


Fig 349 Technic of taking lateral x ray picture of neck of femur (G C. Fogel and H May J A. M. A.)

into the acetabulum of the pelvis. Otherwise it would fall out after the tunnel is drilled (see later discussion under Insertion of Graft)

Removal of Graft A section of the fibula of predetermined length (see the foregoing) is removed subperiosteally from the same side in the usual way (p 65) and kept in moist gauze for the time being

Insertion of Graft Before the graft is inserted a canal is drilled The drills to be used are cannulated fitting on the guide wire. Four sizes are available (Fig 351) The smallest is the starter The proper distance is marked on it with methylene blue. Then follows the next size. After its removal the fibular graft is fed onto the wire. If the canal is still too narrow the next size drill is used until the fibular graft can be inserted The wire is then removed and the wound sutured

After Treatment A plaster cast (single spica) is applied from the toes to the thorax The region of the tuber ischiadicum of the adductors and

light-weight brace, with flexible knee and ankle joint. The nonunion or defect of the tibia may heal in the meantime or may require subsequent bone-grafting. If the tibial defect remains, the fibula, owing to functional stimuli from weightbearing, may hypertrophy to such a degree that walking without support can be permitted.

Double Nonunion

If the tibia breaks in two places and one of the fracture lines happens to run through the entrance of the nutrient artery, the blood supply of the middle piece may be considerably interfered with (May) (see Cases 118, 119, pp 1011, 1012). A double nonunion may be the result, requiring bone-grafting. To bridge and stabilize the middle piece and the lower and upper cleft, a long, massive bone graft should be utilized. The most suitable graft is the fibular, either of the same or of the other side (Case 119, p 1012). This is an extensive operation If contraindicated, a tibiofibular fusion, as described in the foregoing, is the alternative (Case 118, p 1011) Nonunions may heal under this treatment or may need subsequent bone-grafting If this is the case, simple sliding grafts may be all that is required, since the middle piece is stabilized by the tibiofibular fusion

Nonunion of Internal Malleolus

Occasionally, a fracture of the internal malleolus heals with fibrous union. Various theories about the underlying cause have been discussed by Lutzeler. Bone-drilling, with multiple drill holes, has a good chance of curing if union is delayed. In a definite nonunion, however, bone-grafting (pegging) is the surest way to obtain bony union

Technic (Case 122, p 1015). From a longitudinal incision over the internal malleolus, the fragments and the cleft are exposed If the fragments are displaced and widely separated, the scar between the fragments is excised, and the fragments are reduced, otherwise the fibrous-tissue disk is left intact. A canal of proper size (about 5 cm. [2 inches] long) is now drilled obliquely through the malleolus into the tibia. A bone peg, slightly thicker than the drill being used, is removed from the anterior edge of the middle portion of the tibia The drill is now removed and the graft pegged into the prepared canal

After closure of the wound, a cast is applied from the toes to the knee No weightbearing is allowed for five weeks The cast is then changed to a walking-cast, which is wo[illegible] until firm union is demonstrable in the x-ray picture (from ten t[illegible] [illegible]eeks after the operation).

Shaft of Femur· Nonunions and defects are bridged by bone grafts in the usual way Immobilization in a single spica plaster cast, reaching from the toes to the thorax, is necessary (see previous discussion) The intramedullary nail fixation may also be available (see p. 634)

Lower Part of Femur· Defects in this region are difficult to bridge *For nonunions with small clefts, an onlay graft, inserted from a lateral*

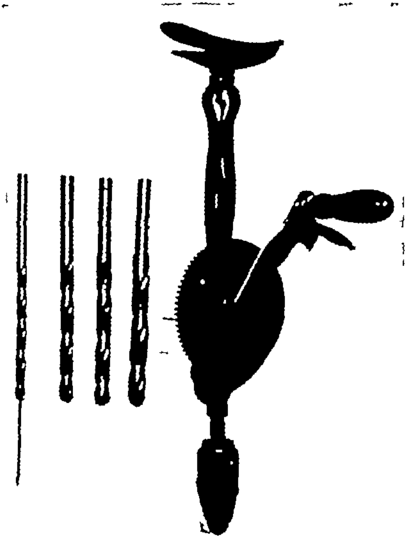


Fig. 351 Cannulated drills of various calibers to be fed over guide wire and to be used for preparing canal in neck of femur for reception of fibular graft.

incision (see p. 627) and fastened with vitallium screws is the most promising method In wide defects, a technic similar to that described for defects of the lower or upper part of the humerus may be tried. The essential point lies in preventing the condylar fragment from rotating forward that is, in counteracting the pull of the calf muscles Semiflexion

consisting of the curved section of the shaft, is rotated 180 degrees and, after some shortening and shaping, replanted The periosteal soft-tissue cuff is then carefully sutured and the extremity encased in a plaster cast It has been frequently demonstrated that, even without reimplantation of the resected bone, the defect becomes bridged by bone regeneration within the periosteal cavity (Bier, Lexer) Healing is more assured, however, by reimplantation of the resected bone, which also counteracts any possibility of shortening.

METAPHYSIS AND EPIPHYSIS

A number of these deformities are of rachitic origin or are osteo dystrophies from endocrine or unknown disturbances (Blount) or traumatic premature closure of a portion of the epiphyseal cartilage plate (Abbott and Gill) (Case 123, p. 1016) Others develop after fractures or infections Only two will be discussed here, genu valgum and genu varum

Genu Valgum

The seat of the deformity is ordinarily found in the distal metaphysis (part between epiphysis and shaft) of the femur. The typical appearance of the deformity is the abduction and slight inward rotation of the leg, causing the so-called "knock-knee" *The correction is by means of* an osteotomy through the median side of the lower metaphysis of the femur, followed by proper alignment of the fragments McEven osteotomizes only the median side, and fractures the lateral side manually in greenstick fashion, thus avoiding lateral displacement of the fragments

Technic (McEven): From a longitudinal incision just proximal to the median condyle of the femur, the thick tendon of the musculus adductor magnus is located The tendinous attachments of the musculus vastus medialis to the adductor tendon are severed. By retracting them anteriorly, the femur is exposed (see also p 628) Just proximal to the epiphysis, a small artery can be seen running horizontally around the bone. It is the deep branch of the arteria articularis genu suprema Close and proximal to this vessel, the periosteum is incised and the bone osteotomized in a plane parallel to that of the knee joint The osteotomy should be only partial, it should not include the lateral cortex, which is fractured by adducting the leg manually The deformity is now corrected, and this should include the slight inward rotation of the leg After closure of the wound, a single-spica plaster cast is applied from the toes to the chest After four weeks, this cast is changed and a shorter cast applied from the toes, including the thigh The cast is to be worn until the roentgenogram reveals complete union.

Deformities

DIAPHYSIS

Of the deformities of the shaft, those caused by rickets and malunion after fracture are amenable to correction while those caused by osteomyelitis syphilis and osteitis fibrosa cannot be attacked owing to the associated massive thickening of the bone.

Technic: In less extensive cases a simple osteotomy through the height of the convexity, followed by proper alignment of the shaft and immobilization in a plaster cast is sufficient. In more severe cases, a wedge-shaped osteotomy (the base of the wedge over the convexity) with removal of a piece of bone of proper width or a curved osteotomy permitting rotation of the fragments in the plane of the curvature or multiple simple osteotomies through the convex side of the shaft are required to straighten the deformed shaft. In selecting the site of the artificial fracture line the height of the convexity should not be the only guide. If possible the shaft should not be osteotomized through the entrance canal of the nutrient artery which may be demonstrable by x ray examination

Technic (Moore) Moore advises a method of osteotomy and osteoclasis By a wedge-shaped osteotomy the long bone is cut almost entirely in two the osteotomy however is completed later by manual osteoclasis The removal of the wedge in the first stage is done so that a strip of cortex remains near the apex This strip is drilled once or twice with a three-sixteenth inch drill The wedge of the bone is cut into small pieces and replaced in the defect. The periosteum is carefully closed over it followed by closure of the wound in layers and application of a plaster cast. After twenty-one days in an individual with growing bones and twenty-eight days in the adult a cylindrical section of the cast is removed at the site of the incomplete osteotomy The intact bone is easily broken manually followed by correction of the deformity The defect in the plaster is then filled in with slabs and circular plaster bandages. The cast is removed after an additional six weeks in children and eight to twelve weeks in adults.

In extreme cases (rachitic curvatures of bones are fortunately rare in this country) a simple osteotomy is not sufficient to correct the deformity Resections with or without reimplantation of bone are required These operations should be performed only after the disease has healed (after the age of six) In performing the operation the most important point is the preservation of the periosteum In the growing age the cambium layer of the periosteum is very active and extreme care should be taken to perform the resection subperiosteally (see p. 61) The resected bone

subperiosteal osteotomy of the fibula is performed with the costotome or chisel The fragments are now brought into alignment, the wounds are closed, and a plaster cast is applied from the toes to midthigh The cast is changed to a walking-cast after four weeks, which should be worn until firm union becomes demonstrable in the x-ray picture

The open-wedge osteotomy (see the previous discussion) may be necessary in extreme cases The technic after Moore is also applicable (p 649)

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Technic (Abbott-Gill) In extreme cases Abbott and Gill recommend the lateral open wedge osteotomy A sufficiently long incision is made on the lateral aspect of thigh and knee to lengthen the structures in this region (for incisions see p 627) The biceps tendon is divided in Z-fashion the peroneal nerve the greatest obstacle to full correction is freed down to the neck of the fibula the lateral head of the gastrocnemius is severed from the lateral epicondyle and fasciae and fascial expansions resisting lengthening are severed The bone is osteotomized just above the lateral epicondyle in a plane parallel to that of the knee joint. The site of the osteotomy is wedged open as far as possible without too much stretching of the peroneal nerve whose tension may be relieved by slight flexion of the knee joint. A triangular full thickness graft of iliac bone is used to fill the opening wedge (for removal of this graft see p 63) The graft is held in place with a transfixing pin which is passed from the ledge of the distal fragment across the site of the osteotomy and graft into the proximal fragment. After closure of the wound the extremity is immobilized in a plaster cast.

If full correction cannot be obtained at the time of the operation the transfixing pin is left long to protrude through the skin and to be incorporated in the cast After five weeks it is withdrawn from the proximal fragment but left in graft and distal fragment. A turnbuckle is applied on the lateral side of the cast and a hinge on the medial side. The cast is then cut at the level of the site of the osteotomy and wedging is begun until full correction has been obtained or until symptoms of stretching of the peroneal nerve ensue

Technic (Moore) See p. 649

If compensatory deformity of the tibia is present, it should be corrected by a second oblique osteotomy on the median side of the tibia in a similar open wedge procedure This operation is performed after the site of the femoral osteotomy has firmly united

Genu Varum

The deformity usually occurs at the upper metaphysis (part between upper epiphysis and shaft) of the tibia

Technic (Case 123 p 1016) From a longitudinal incision over the anterior border of the upper metaphysis of the tibia the periosteum is incised along the anterior border and the periosteum and muscles are retracted laterally The curved part of the tibia is now osteotomized through the lateral and anterior cortex in a plane parallel to that of the knee joint. The remaining part of the cortex is fractured manually in greenstick fashion while the deformity is corrected Prior to this step however a

XXVI

THE ARTICULATIONS

Reparative and reconstructive surgery of the joints has a wide field of application. A detailed description of the whole subject would be far beyond the scope of this book, particularly since much of this surgery belongs to the orthopedic field Only arthroplasty and joint transplantations have been selected for short discussion in this chapter

Surgical Approaches

SHOULDER JOINT

The shoulder joint is a complex mechanism consisting in reality of several joints which act separately or in unison A fine description of the anatomy and function of the mechanism and of the various approaches is presented by Abbott and his associates

Technic (Henry) (Fig 352, see also Figs 331–332) An incision is made along the median border of the musculus deltoideus, following the cephalic vein from its origin to the clavicle At the clavicle, the incision turns laterad and follows the clavicle. The origin of the musculus deltoideus at the lateral third of the clavicle is severed either subperiosteally or through the muscle substance The cephalic vein is now located Beneath the vein, one finds the interval between the musculus deltoideus and the musculus pectoralis major This space is opened The median portion of the musculus deltoideus, thus freed from the clavicle and the musculus pectoralis major, is reflected laterally This approach offers ample exposure of the anterior subdeltoid structures Extension of the incision beyond the acromion, along the spine of the scapula, may be necessary in exceptional cases

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ELBOW JOINT

Technic (Posterior U-Incision) (MacAusland) (Figs 353–354) The arm is placed in such a way that the olecranon is the uppermost part A U-shaped incision is made from one epicondyle, around the base of the olecranon, to the other epicondyle The ulnar nerve is now exposed and freed from its sulcus It is safeguarded by holding it aside with a piece of gauze The olecranon is severed from its base with a chisel or

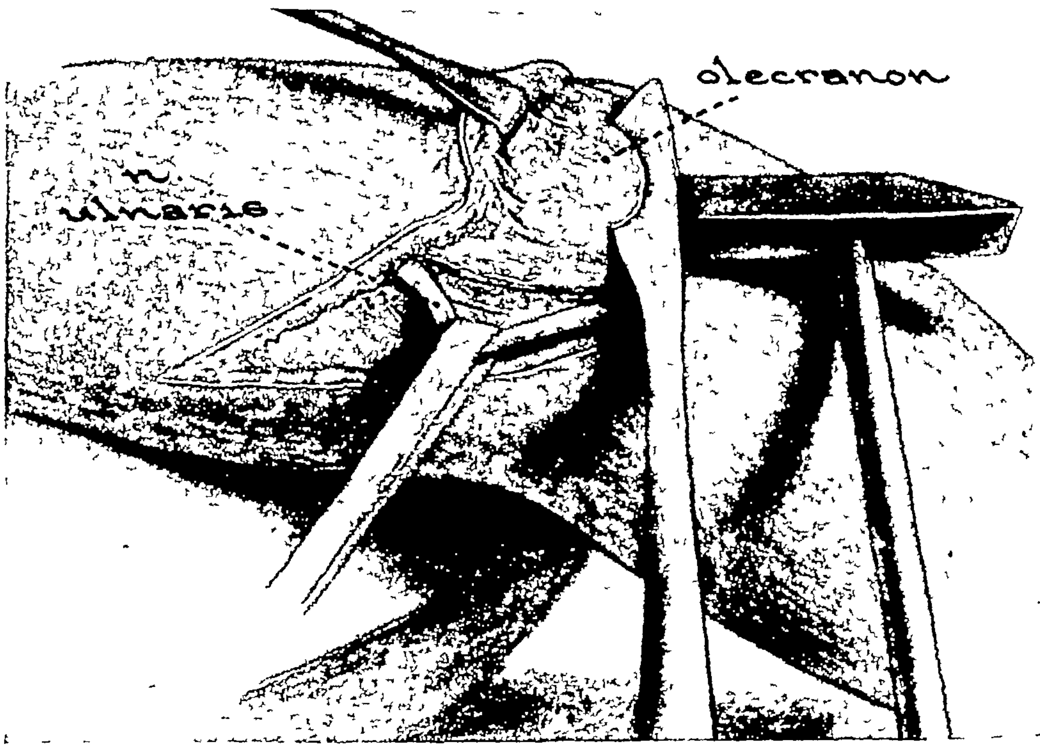

Fig 353 Approach to elbow joint from posterior U-incision (MacAusland) Severance of olecranon Exposure and retraction of nervus ulnaris

a bone knife and, together with triceps tendon and muscle, is reflected proximally

When the wound is closed, the olecranon is fastened to its base at the ulna by suturing the periosteum The ulnar nerve is replaced into its groove at the lateral epicondyle and the wound closed in layers

Technic (Exposure of Radiohumeral Joint): See p 623

HIP JOINT

Technic (Anterior Approach after Smith-Petersen) (Figs 355–356) An incision is made along the anterior third of the crest of the ilium (or farther posteriorly if necessary), over the spina iliaca anterior superior, curving downward and somewhat laterally After division of superficial

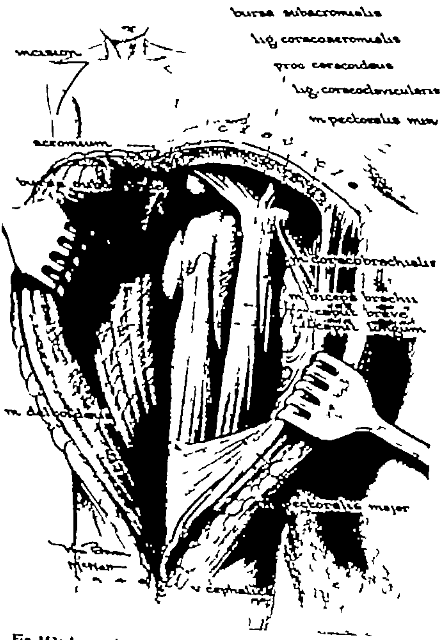

Fig. 352: Approach to shoulder joint by reflecting median portion of musculus deltoideus laterally (Henry)

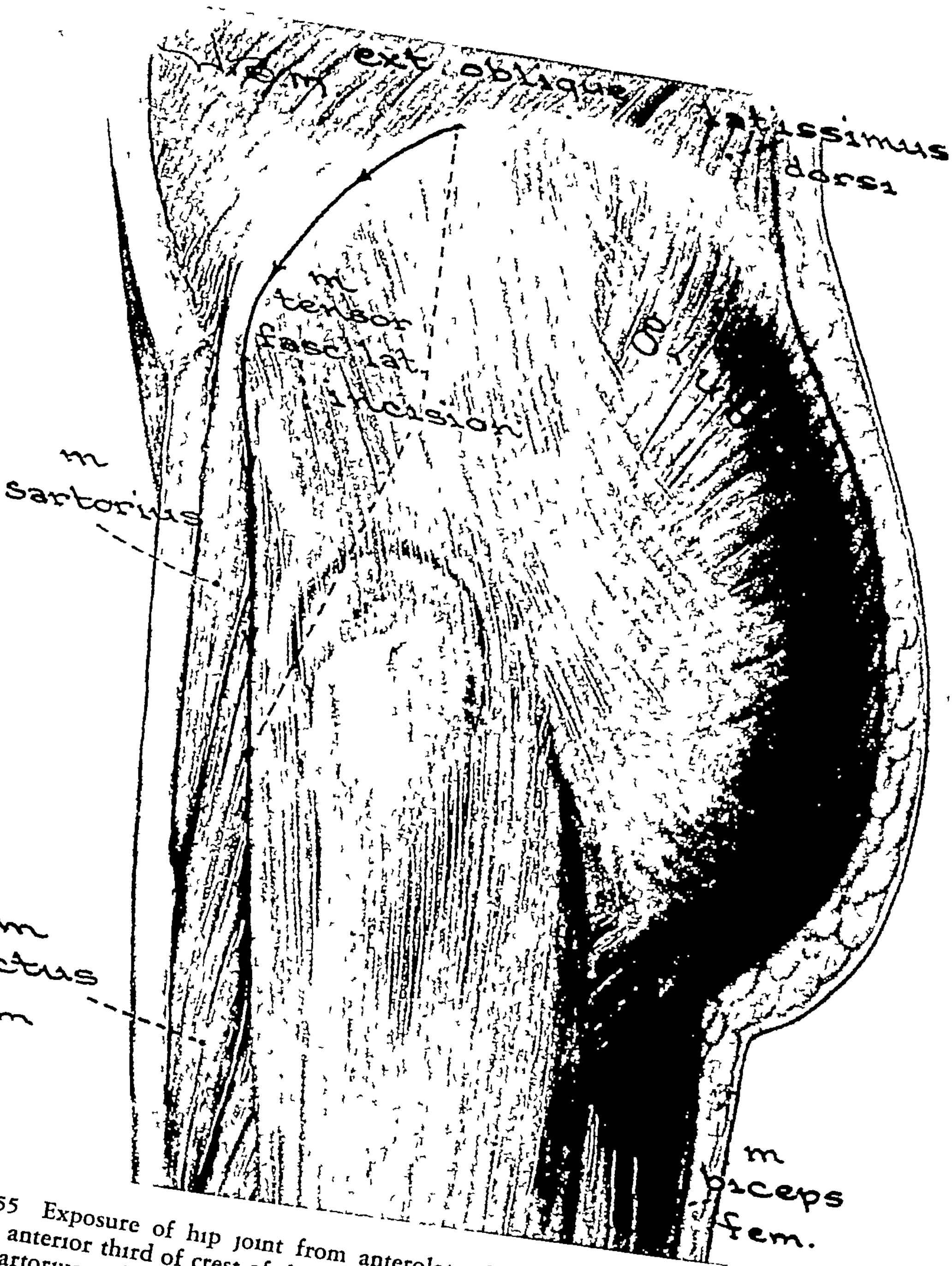

Fig 355 Exposure of hip joint from anterolateral incision (Smith-Petersen) Incision along anterior third of crest of ilium over spina iliaca anterior superior and between musculus sartorius and tensor fasciae latae

and deep fascia the musculus glutaeus medius and musculus glutaeus minimus are subperiosteally *detached from the crest* and the lateral surface of the ilium The deep fascia of the thigh is now incised along the interval between the musculus sartorius and the musculus tensor fasciae latae Care should be taken not to injure the nervus cutaneus femoris lateralis as it passes from below the spina iliaca anterior superior over the musculus sartorius The musculus sartorius is retracted medially the muscu

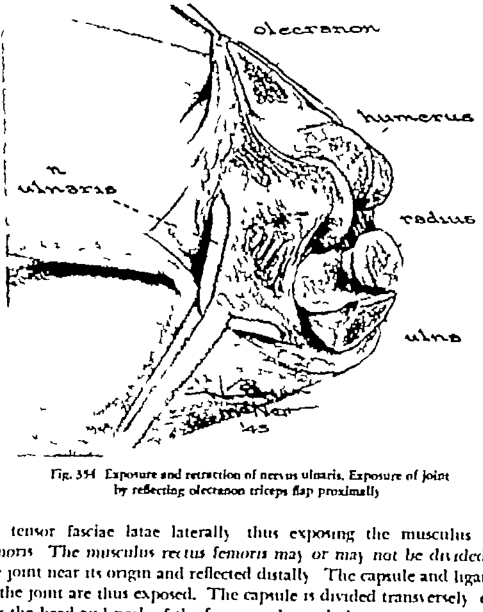

Fig. 354 Exposure and retraction of nervus ulnaris. Exposure of joint by reflecting olecranon triceps flap proximally

lus tensor fasciae latae laterally thus exposing the musculus rectus femoris *The musculus rectus femoris may or may not be divided over* the joint near its origin and reflected distally The capsule and ligaments of the joint are thus exposed. The capsule is divided transversely expos*ing the head and neck of the femur and acetabulum*

Smith Petersen revised his technic slightly later on In some cases in which it was found necessary to sever the rectus femoris and a short stump of it was left attached to the inferior iliac spine this stump became calci

fied after the tendon was resutured This difficulty has been overcome by dividing the rectus tendon close to the inferior spine, then suturing it at the end of the operation to the reflected head of the rectus, or to the tendon of the gluteus minimus

Technic (Lateral U-Incision) (Murphy) (Figs 357–358) The patient is placed upon the sound side The incision starts posteriorly and below the spina iliaca anterior superior, curves around the greater tro

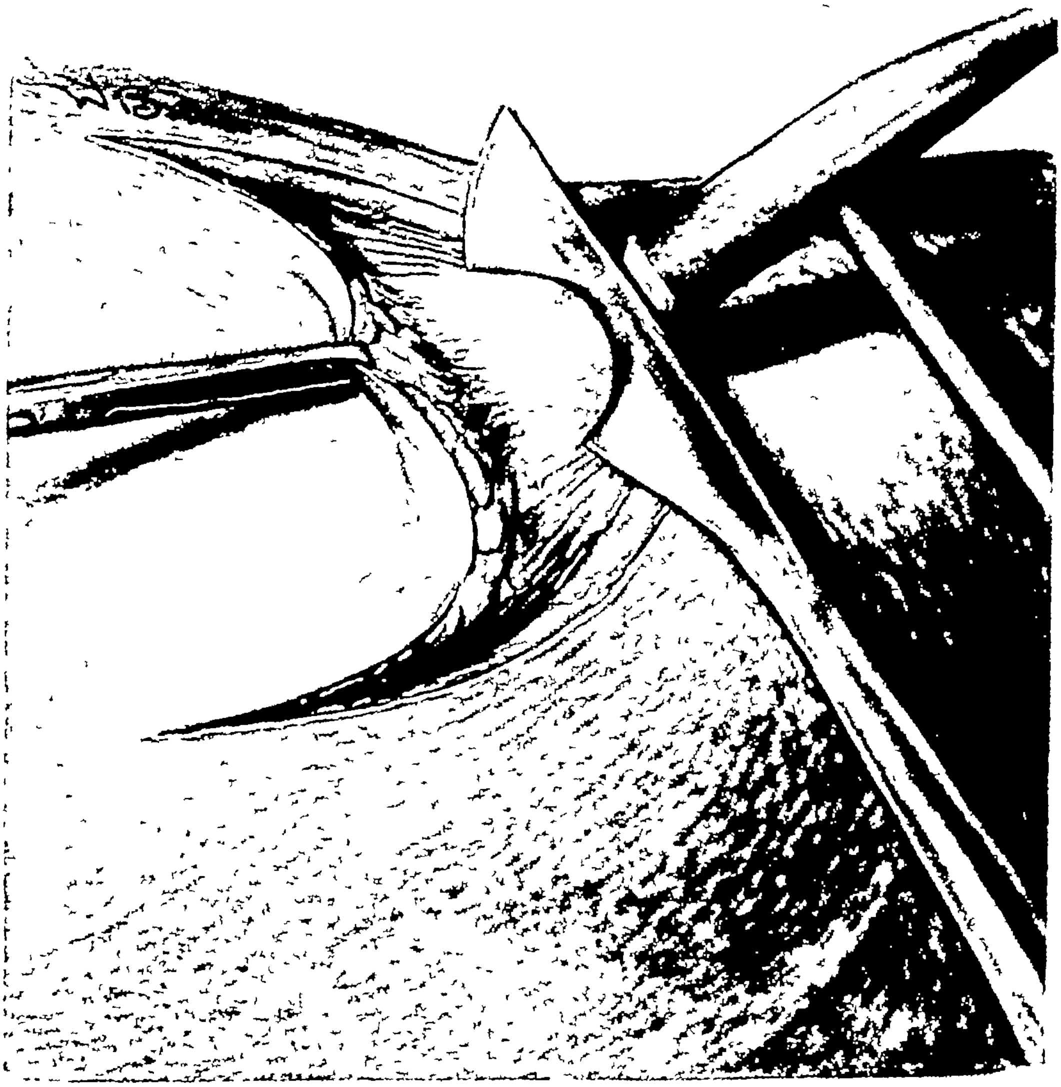

Fig 357 Exposure of hip joint from lateral U-incision (Murphy). Greater trochanter is severed obliquely

chanter, and ascends behind it to the level of the starting-point The greater trochanter is severed obliquely from below outward to above inward and, together with the inserting muscles (glutaeus medius and minimus), reflected proximally, whereby the tensor fasciae latae is incised and the glutaeus maximum reflected posteriorly This exposes the entire

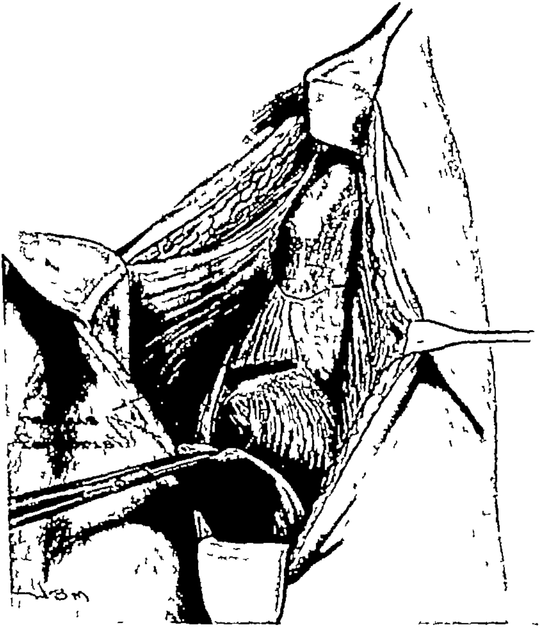

Fig. 356: Joint is exposed by retracting musculus sartorius medially tensor fasciae laterally and dividing musculus rectus femoris near or better at its origin (see text)

Considerable interest has been aroused in the modified Kocher approach through Gibson, and through McFarland and Osborne

Technic (Posterolateral Approach)· From a curved incision which starts 7 5 cm (three inches) anterior to the spina iliaca posterior superior curves downward to anterior border of the trochanter and follows the femur along the anterior border of the musculus glutaeus maximus The

Fig 359 Exposure of knee joint from anteromedian S-incision (Payr)

upper limb of the incision may not need to be as long as described The greater trochanter is exposed The insertion of the musculus glutaeus medius and of the glutaeus maximus are severed antero-posterior and reflected proximally The joint capsule is exposed and excised with a curved incision along the lateral insertion The head of the femur is then dislocated out of the wound in a similar way as described in the foregoing approach When the wound is closed the divided tendons are sutured

region between acetabulum and trochanter The capsule is incised transversely exposing the joint If wider exposure is needed to dislocate the upper part of the femur temporarily out of the wound for instance the tendons of the musculus periformis and the musculus obturator internus must be severed from the posterior surfaces of the neck of the femur the fossa intertrochanterica This should be done in such a way as to permit

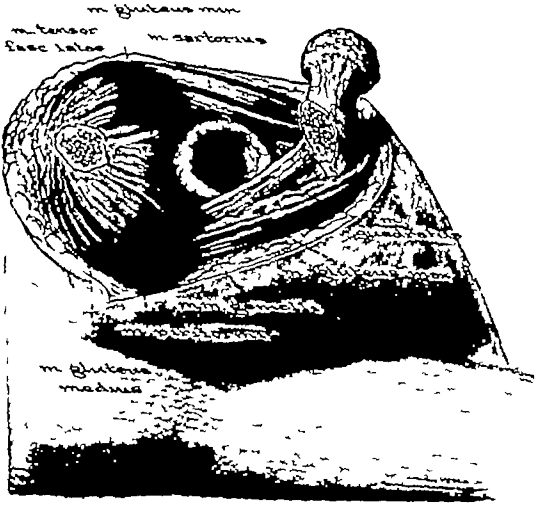

Fig. 358 Severed trochanter together with inserting muscles, is reflected proximally Musculus piriformis, musculi gemelli, and musculus obturator internus are severed from fossa intertrochanterica. After incision of ligaments and capsule femur is dislocated by inward rotation and adduction of leg.

later suture. Under outward rotation and adduction of the leg and severance of the ligaments including the *ligamentum teres femoris* the upper end of the femur can be dislocated out of the wound

When the wound is closed the divided tendons are sutured The greater trochanter is replaced to its base and fastened to the femur with periosteal sutures or with a nail

Technic (Lateral Approach) (Kocher) (Fig 360) The incision runs 2 cm (3/4 inch) posterior to the distal 10 cm (4 inches) of the fibula, curves around the lateral malleolus, and terminates 3 cm (1 3/16 inches) median to the tip of the malleolus The fascia is incised along the peroneal tendons The tendon sheaths of the latter are incised and the tendons dislocated from behind the malleolus The tendons may be left

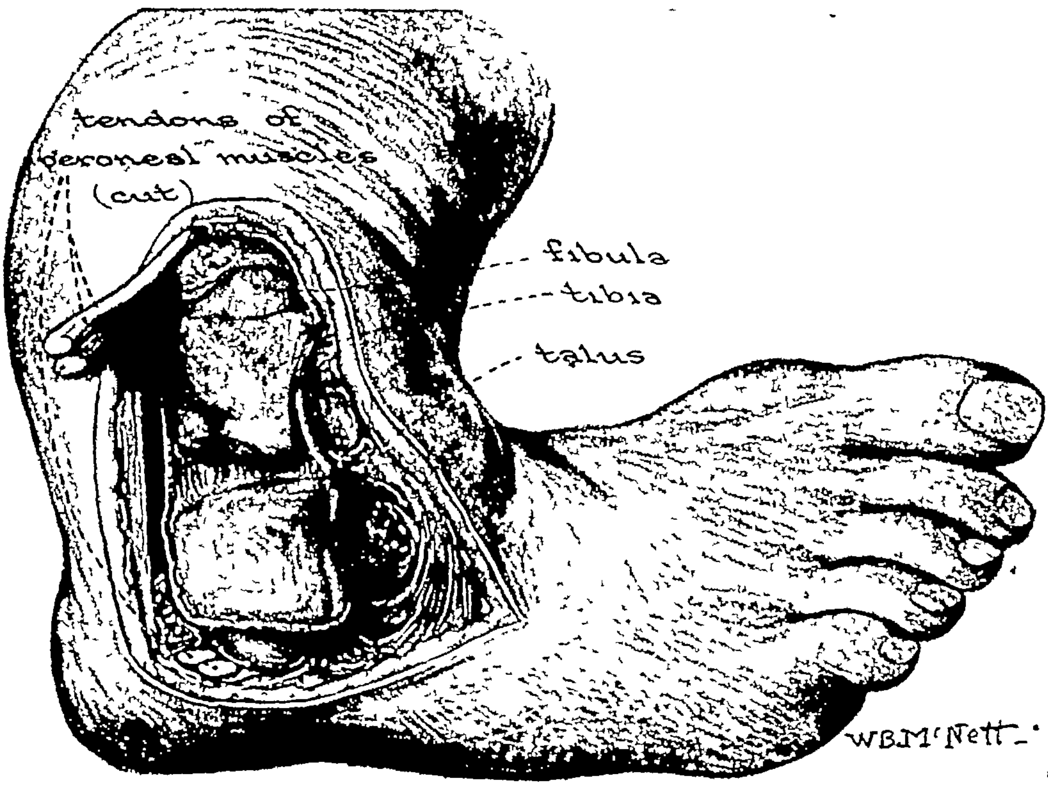

Fig 360 Exposure of ankle joint from lateral incision (Kocher) Temporary division of peroneal tendons and dislocation of ankle joint

intact or may be temporarily severed and retracted to obtain wider exposure Dissection is continued anteriorly over the anterior surface of the malleolus, severing the origin of the musculus extensor digitorum brevis and exposing the ankle joint The posterior surface of the malleolus and ankle joint is now dissected free The ligaments connecting the malleolus lateralis and tibia with the middle portion of the foot are severed, and the joint is opened When the foot is bent medially, the joint surfaces become well exposed

Arthroplasty

The first attempts at mobilizing ankylosed joints were made at the end of the last century Helferich (1894) is given the credit for having per-

KNEE JOINT

Technic (Anteromedian S-Incision) (Payr) (Fig 359) The incision commences along the median border of the quadriceps tendon curves around the median rim of the patella continues along the ligamentum patellae, and ends at the tuberculum tibiae Skin and superficial and deep fasciae are incised and the space between the musculus vastus medialis and quadriceps tendon is opened The joint capsule is now incised The incision is continued distally between patella and collateral ligaments. If the patella is retracted laterally and the knee joint flexed 90 degrees the anterior compartment of the knee joint is well exposed

Technic (Anterior U Incision) (Kocher Textor) (Figs. 360–364) The incision starts at one of the femoral condyles curves around the distal portion of the tuberositas tibiae and ascends to the other condyle. After separation of skin and fascia the tuberositas tibiae is obliquely severed either with a chisel or with a bone knife The median and lateral parts of the incision are deepened through deep fascia and joint capsule. The entire flap is now lifted up and reflected proximally

When the wound is closed the tuberositas tibiae is returned and fastened to the tibia with a nail The wound is closed in layers

ANKLE JOINT

A good review of the various approaches to the ankle joint has been presented by Colonna and Ralston

Technic (Anterolateral Approach) Campbell calls this the "universal incision for the foot and ankle. It gives excellent exposure of ankle joint and other tarsal bones and joints

The incision starts 5 cm (2 inches) proximal to the ankle joint midway between fibula and tibia runs over the anterolateral aspect of the ankle joint and terminates at the base of the fourth metatarsal bone Fascia and ligaments (ligamentum transversum cruris and ligamentum cruciatum cruris) are severed The incision penetrates down to the periosteum of the tibia and capsule of the ankle joint. The musculus extensor digitorum brevis is divided longitudinally The long extensor tendons, together with the deep peroneal nerve and the arteria dorsalis pedis are retracted medially The ankle joint thus exposed is incised transversely With the dissection continued medially beneath the tendons, the talonavicular joint is opened while laterally the calcaneocuboid joint becomes accessible By prolongation of the incision distally the other joints of the middle portion of the foot can be reached

cises should not be forced beyond tissue tolerance Upon evidence of exertion (pain, tenderness, hyperemia, swelling), the limb must be immobilized and all physical therapy interrupted until active symptoms have subsided.

Morphological Changes in Fascia-Fat Graft: As already mentioned, the fascial side of the graft is fastened to one of the raw bony surfaces The opposite side of the graft, consisting of fat tissue only, comes in close contact with the other raw joint surface by the normal relationship of the joint, and fills out all irregularities owing to its softness The various layers of the graft undergo certain regenerative, degenerative, and functional changes Those parts of the graft which are in close contact with the articular surfaces survive, while the central parts degenerate, forming vacuoles and cavities filled with liquefied fat, so-called "oil cysts" Later, upon motion, the cavities are broken up, and a joint cleft is formed The liquefied fat becomes absorbed The surviving peripheral layers of the graft, forming the covering of the articular surfaces, undergo metaplastic changes when placed under pressure and friction from joint motions, changing into fibrous tissue at first and later into fibrocartilage

Indications and Contraindications In selecting a case for arthroplasty, the patient has to be judged by his social, occupational, general physical, and local status Weak persons should be excluded, since the after-treatment is strenuous, requiring the full active cooperation of the patient, also to be excluded are those persons who have strenuous physical occupations

Joints ankylosed from rheumatic arthritis should not be mobilized As a rule, ankylosis recurs after a short time, owing to proliferation and contraction of the periarticular fibrous tissue Tuberculous joints and gonorrheic joints are also unfavorable, particularly if mobilized too early The best results are obtained in joints ankylosed from acute pyogenic infection or trauma In cases of pyogenic infection, one ought to wait at least six months after the infection has subsided before performing the operation Preoperative and postoperative antibiotic therapy is strongly indicated in these cases If muscles are destroyed from suppuration or multiple incisions, however, arthroplasty is contraindicated In traumatized joints, the indication for arthroplasty arises from the incongruous joint surfaces, after fractures In recent cases with marked comminution and displacement of fragments, a two-stage operation is advisable In the first stage, the displaced fragments are reduced as well as possible by an open reduction and fastened together with wires and nails, thus, the articular forms are restored to some extent After the first callus has developed, from four to eight weeks later, the joint is reopened and

formed the first arthroplasty in the modern sense, he mobilized an ankylosed mandibular joint, and interposed a muscle flap from the temporal muscle Murphy (1905) however, must be given credit for having popularized this method he transferred the principle of the flap interposition to other joints. Lexer (1906) simplified the method by using instead of a flap, a free graft of fat tissue while Payr and Putti became advocates of the fascial graft. They were followed in this country by Baer Henderson MacAusland and Campbell Smith-Petersen although preceded by others in the use of foreign material introduced vitallium cups in arthroplasties of the hip joint. Soon other types of foreign material were advocated such as radiotransparent cups of methacrylate resin (Harmon and others) cellophane (Wheeldon McKeever) Buxton in his recent monograph deals with this subject from most points of view and with authority

Arthroplasty consists in severance of the synostosis formation of articular surfaces, and interposition of tissue which prevents recurrence of the ankylosis and allows the articular surfaces to glide against each other In the following technics a graft of fat tissue and fascia is used for interposition

GENERAL TECHNIC

Operation (Figs. 361–364) The joint is opened with an incision which permits adequate exposure without interfering with future function Since exact hemostasis is necessary no tourniquet should be applied The important ligaments are left intact or severed from their insertion near the bone in such a way that they can be reattached subsequently If the ankylosis is due to fibrous adhesions the latter are severed The cicatricial *joint capsule is removed as thoroughly as possible,* particularly from the posterior spaces. The joint surfaces are now freshened with chisel or saw whereby normal contours should be imitated In bony ankylosis the synostosis is severed at the level of the joint cleft, with a wide chisel or saw The joint surfaces are modeled until a cleft of a fingerbreadth is created A graft of fascia lata and fat tissue is removed from the latero-posterior surfaces of the thigh (see p 43) The fascial surface of the graft is placed upon one of the raw bony surfaces and sutured in place Then follows closure of the wound in layers

After Treatment The extremity is immobilized in a plaster cast for from two to four weeks The cast is then removed temporarily, and physical therapy is given daily under expert supervision starting with massage and active motion exercises The cast may be entirely discarded after another week and passive motion exercises are added Active and passive motion exercises should go hand in hand. Passive motion exer

Formation of Articular Surfaces: After removal of the cicatricial capsule, the bony ankylosis is severed with a large curved chisel from above outward to below inward Under extreme flexion, adduction, and outward rotation of the leg, the synostosis is gradually broken up and the upper part of the femur lifted out of the wound The raw bony surfaces are now remodeled with a chisel to almost normal contours Any uneven edges on the femur, as well as in the acetabulum, are smoothed with a special reamer.

Interposition of Graft: The fascia-fat graft is taken from the same leg by adding a lateral longitudinal incision to the most distal border of the original incision The fascial side of the graft is laid upon and around the newly formed head of the femur and sutured in place Under strong traction and countertraction, the femur is reduced and the wound closed in layers Since Smith-Petersen's introduction of foreign-body cups for interposition in hip arthroplasty, the method has gained wide acceptance (Law, Adams, Devas, etc) These cups are made of inert substances, such as vitallium (Smith-Petersen, Venable and Stuck) or methacrylate plastics (D'Aubigné, Harmon) They come in certain standard sizes and should fit loosely on the femoral head The cup arthroplasty has recently been challenged by the prosthetic replacement arthroplasty (of the Judet brothers) There is strong evidence, however, in favor of the defenders of the cup arthroplasty (Adams, Aufranc, etc) As one reviewer acclaimed the recently published book of the Judet brothers "it is a very great pity that this book did not appear in 1950, for that year saw the start of the acrylic-rush in British surgery much trouble might have been saved " However, in cases of much loss of the femoral head and neck the prosthetic replacement is of undoubted value (D'Aubigné and Pastel, etc)

In case of adduction contracture, a subcutaneous tenotomy of the adductors should be performed (see p 566)

After-Treatment: To protect the graft from pressure, adhesive-plaster traction should be applied to the leg A double-spica plaster cast is now applied, reaching from the ankle of the operated side and the knee of the sound side to the chest. When the patient is in bed, 10-pound traction is applied to the adhesive strips and, the traction running over pulleys, fastened to the foot of the bed to Buck's extension apparatus The cast is removed after four weeks, while traction remains applied or is reapplied for two more weeks In the meantime, massage and active-motion exercises are instituted, the latter by means of a sling beneath the knee joint and pulleys attached to an overhead frame The patient is allowed out of bed and on crutches six weeks after the operation. Passive

arthroplasty performed If only one joint surface is injured, the other being intact the latter is left intact and only a hemiarthroplasty performed (Case 124 p 1018)

The joints most amenable to arthroplasty are the elbow hip knee and jaw Arthroplasty of the latter has been described on p 450

ELBOW JOINT

Exposure The elbow joint is exposed as depicted in Figs. 353–354 The collateral ligaments if present, are left intact or if their severance becomes necessary are severed from the humeral epicondyles close to the bone and reflected downward. The next step is removal of the fibrosed and cicatricial capsule.

Formation of Articular Surfaces. In fibrous ankylosis, the binding strands of fibrous tissue are severed until the joint can be completely flexed In bony ankylosis a joint cleft is made by transverse separation of the bone with a wide chisel The arm is flexed and the bony surface of the humerus is rounded with chisel and rasp to form one condyle while ulna and radius are fitted correspondingly with a curved chisel to form the saddle of the joint If the radioulnar articulation is ankylosed enough bone is excised to form a cleft 1 cm. (⅜ inch) wide

Interposition of Graft A graft of fascia and fat tissue is removed from the thigh (see p 43) and its fascial side sutured to the humeral joint surface At first, it is anchored to the soft tissues of the anterior side close to the bone with a few catgut sutures. Then after the arm has been extended under moderate traction it is sutured to the periosteum of the humerus, close to the base of the triceps flap Another small graft is placed between ulna and radius

Closure of Wound The triceps flap is reflected downward and the olecranon fastened to its base by suturing the periosteum The ulnar nerve is replaced the collateral ligaments if severed are sutured to the humeral epiphysis then follows closure of the remainder of the wound in layers.

After Treatment The arm is semiflexed and immobilized on a posteriorly molded plaster-cast splint reaching from the knuckles to the shoulder After two weeks the splint is temporarily removed and active motion is started After another week the splint is discarded, and passive motion exercise and massage are added (see also p 665)

HIP JOINT

Exposure The joint is exposed from a postero-lateral or an antero-lateral incision Since Gibson's admirable description of the Kocher Technic the lateral approach has become popular (p 662)

Exposure The joint is exposed by a U-shaped incision (see Figs 361–364) The collateral ligaments, if present, are severed from their insertions at the femoral condyles and retracted downward Sometimes, if only faint traces of them are left, it is better to sever both their insertions, the femoral and tibial, but to leave them attached to the U-shaped flap so that they can be subsequently fastened at their new positions When the structures of the flap are severed, the entire flap is lifted up In bony

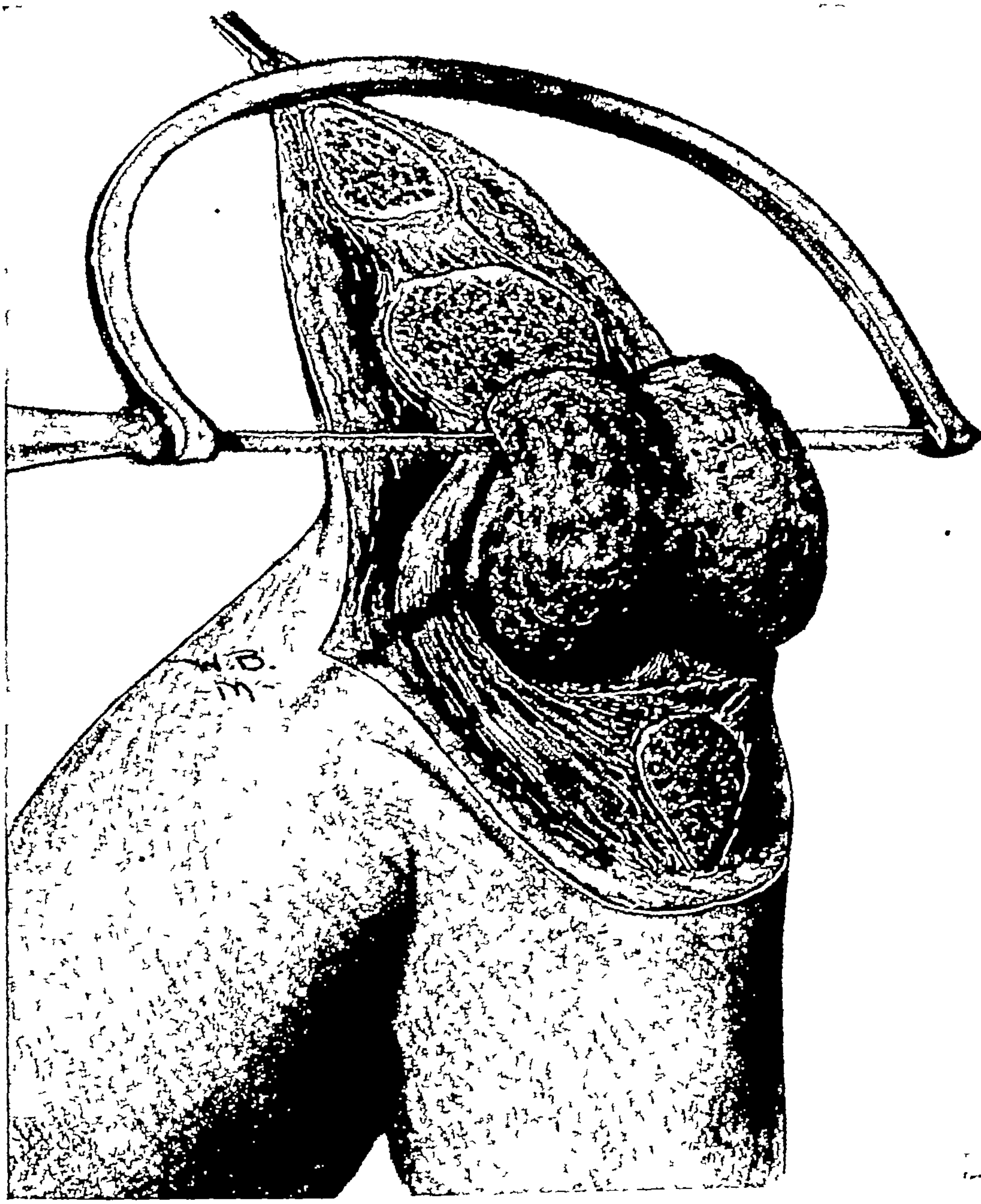

Fig 362 Tuberositas tibiae, ligamentum patellae, and patella, which was ankylosed, are reflected proximally Diseased joint surface of femur is removed with saw and remodeled

exercises (such as furnished by stationary bicycle) are now added. Crutches may be discarded after two or three months (see also p 665)

KNEE JOINT

A careful follow up of patients after knee joint arthroplasty study conducted in two famous clinics by Samson (Montreal) and Speed

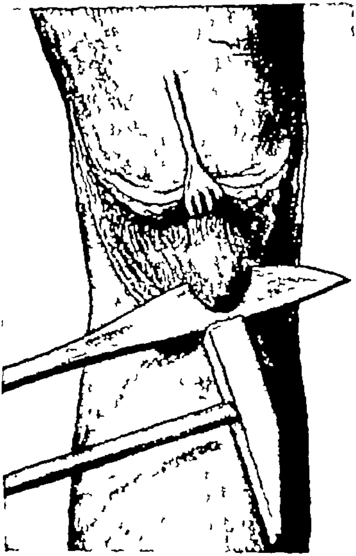

Fig. 361 Exposure of knee joint from anterior U-incision (Kocher Textor) Tuberositas tibiae is severed obliquely

Trout and Boyd (Memphis) and the constructive criticism of Sir Reginald Watson Jones as brought forth in his discussion of these papers, point to the fact that more than in any other joint plasty the patient must be carefully selected and evaluated to make the proper choice between arthroplasty or arthrodesis

of the condyles by dissecting the wound edges and soft tissues away. In flexion ankylosis, this is not difficult. The posterior recess is freed by pushing the soft tissues away with a blunt instrument The latter is left in place for protection of the vessels while the synostosis is severed. The synostosis is severed with a saw, the type of which is pictured in Fig 362 If the joint is ankylosed in extension, the separation is performed without previous tunneling the popliteal space The greater part of the synos-

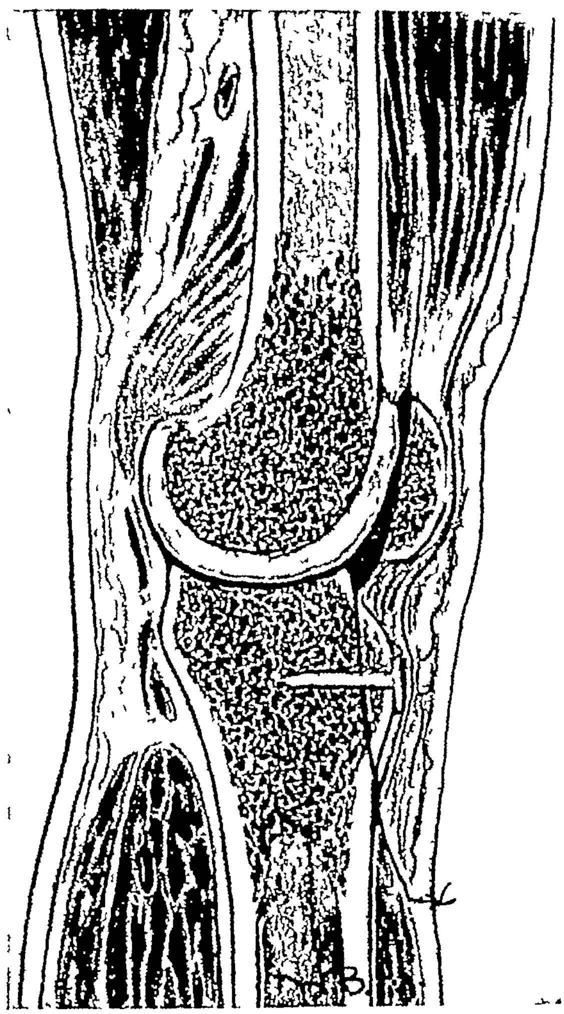

Fig 364 Wound is closed by returning tibial tubercle, which is fastened to tibia with nail Remainder of wound is closed in layers

tosis is severed and the remainder fractured manually. Then follows the formation of the articular surfaces, as described. Sufficient bone should be removed from each side—mainly with the saw—to obtain a joint cleft 2 cm. (3/4 inch) wide.

Interposition of Graft (Fig 363): The fascia-fat graft is taken from the thigh of the same side. It is placed with its fascial side upon the femoral condyle and sutured in place so that the entire raw surface of the

ankylosis the synostosis of the patella must be severed with a wide chisel before the flap can be retracted.

Formation of Articular Surfaces In fibrous ankylosis the cicatricial bands are severed while the leg is gradually flexed The fibrosed capsule, cruciate ligaments and menisci are removed The articular surfaces are now modeled with saw and chisel (Fig 362) The femoral part is made one condyle, and the tibial surface is excavated to form the saddle of the

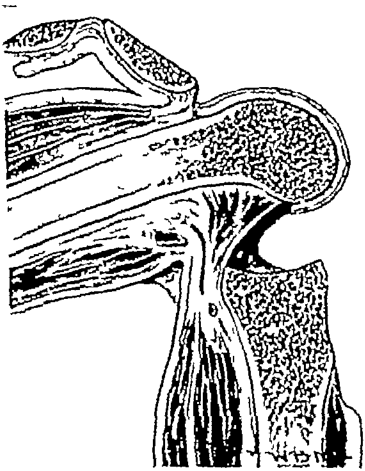

Fig. 363 Joint surface of tibia is remodeled. Remodeled joint surface of femur is covered with a fascia-fat graft with fascial side upon the bone Graft also covers facies patellae of femur

joint Enough tissue should be removed to dispose of all cartilage and cicatricial and diseased tissue until healthy bleeding spongiosa is encountered

The formation of articular surfaces in bony ankylosis is more difficult. Sometimes one finds a shallow groove along the original joint cleft or traces of the latter in the x ray picture. In case of absence of any guiding direction the synostosis is severed through its widest part Prior to that however one must free the lateral median and posterior borders

condyle including the facies patellae of the femur, is covered. The leg is now extended under traction Any parts of the graft protruding laterally and medially are removed with scissors to make room for the reinsertion of the collateral ligaments

Closure of Wound (Fig 364) The soft tissue flap is reflected downward and the tuberositas tibiae fastened to its original site either by suturing the periosteum or by a simple vitallium nail Then follows accurate suture of the fascial structures and reinsertion of the collateral ligaments with silk sutures to the periosteum of the condyles

After Treatment After closure of the wound and application of a pressure dressing an adhesive traction dressing is applied to the leg similar to that previously described. Not more than 8 pounds of traction should be used to avoid overstretching the ligaments. A plaster cast is applied from the ankle to the thigh In cases in which the collateral ligaments are absent, no traction dressing is used. Exercises, in the form of quadriceps contraction should be started two days after the operation The cast is removed after three weeks and active exercises instituted (see former discussion) Massage and passive exercises are added after another week. The patient is allowed to walk on crutches six weeks after the operation weightbearing is permitted twelve weeks after the operation

In hemiarthroplasty of the knee joint only one joint surface—the diseased surface—is remodeled (Case 124 p 1018)

Transplantation of Joints

In discussing joint transplantation it is important to distinguish between transplantation of an entire joint and transplantation of half a joint. Lexer (1907) was the first to perform transplantation of entire joints This startling operation mostly performed for replacement of ankylosed joints was soon given up by its originator and replaced by simpler operations namely arthroplasty Nevertheless, of the twenty three cases in which Lexer performed such homologous transplantation twelve cases resulted in healing of the transplant and mobility remained for a number of years. Later however mobility decreased and became painful owing to extensive arthritic changes from subarticular break down of the subchondral cancellous bone. Two of these patients—the transplant for one was taken from an executed criminal—were followed for fourteen and sixteen years, respectively

These consequences are apparently less serious in homologous half joint transplantations where only one epiphysis is transplanted (Case 125 p 1020) They are entirely absent in autogenous half joint transplanta

kept in midposition between pronation and supination. The arm should remain immobilized for at least three months A light, leather brace is then applied, and is removed daily for bathing the arm and cautious active-motion exercises during the bath. Rotary movements of the forearm, however, should be avoided. The brace is discarded only after there is evidence of firm fusion and regeneration of the graft (five to six months postoperatively).

HOMOLOGOUS TRANSPLANTATION OF HALF A JOINT

The fact that any bone transplant, whether transplanted from the same or another person, dies in most part and does not become regenerated per se but by ingrowth of osteoblasts from surrounding bone regenerative tissue—and this is true to a certain extent with articular cartilage (see p 60)—explains why homologous bone grafts can become regenerated Lexer and others have reported a number of half-joint transplantations However, in larger joints the success seems to be only temporary (Case 126, p 1022)

HETEROLOGOUS TRANSPLANTATION OF A JOINT

This method recently has become popular in replacement of the femoral-head and neck (half joint transplantation) as introduced by the Judet brothers, of Paris (see also remarks on p 668) It has less often been used in other joints (shoulders, etc) It is a precise operation demanding careful selection of the patient, points which have been extremely well stressed by the Judet brothers in their book There are various types of prosthesis available made of various materials It would be beyond the scope of this discussion to go into details The reader is referred to the publications of Judet, Thompson, and D'Aubigné

Recently attempts have been made to replace entire joints with foreign body substances, such as acrylic or vitallium prostheses MacAusland reported a case of an entire knee joint replacement by a vitallium prosthesis This new approach to the problem of mobilization of a joint is very stimulating but still in the pioneering stage

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capsule The proximal end of the lower fragment is prepared for reception of the fibular graft by removal of the anterior half of the cortex (see also p. 636)

Removal of Fibular Graft Head and shaft of the fibula of sufficient length are removed as described on p 628

Transplantation of Fibular Graft The head of the fibula is placed into the glenoid of the scapula while the lower part of the graft is fastened to the humerus with two stainless steel wires. If the capsule of the joint can be preserved, it is closed around the upper part of the graft. If it is absent, the head of the fibula may dislocate from the glenoid To prevent this, Watson Jones made the good suggestion to drill a canal obliquely through the head of the fibula from below upward to sever the long biceps tendon to thread the upper end through the canal and to resuture the tendon as it is done in the Nicola operation for habitual dislocation of the shoulder The detached muscles are now laid closely around the graft and sutured to the soft tissues not to the graft

After Treatment After closure of the wound the arm is abducted 90 degrees and a plaster cast is applied around thorax and arm similar to that described on p 637 The cast is left in place for at least three months The anterior half of the forearm portion of the cast is then temporarily removed and active- and passive motion exercises are instituted to elbow and wrist joint The remainder of the cast is removed after evidence of firm fusion and regeneration of the graft is demonstrable (five to six months postoperatively)

Technic (Replacement of Radial Part of Wrist Joint) The distal part of the radius is removed from an incision as outlined on p 623 The distal part of the radius is exposed by dissecting the soft tissues away With a Gigli saw the shaft of the radius is severed at a predetermined level By pulling the distal fragment out of the wound the remaining adherent soft tissues are severed The ligaments and joint capsule are dissected away from the radial epiphysis and the diseased bone is removed Then follows thorough hemostasis

Transplantation of Fibular Graft The proximal part of the fibula is removed as described on p 628 It is placed in the prepared graft bed so that the head of the fibula replaces the radial epiphysis Only after the articular surface fits snugly into the joint the shaft of the fibula and of the proximal part of the radius facing each other are freshened until the medullary cavities are exposed. Both bones are fastened together with two stainless-steel wires.

After Treatment A plaster cast is applied from the knuckles to the upper arm with the elbow joint in 90-degree flexion and the forearm is

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SECTION TWO

THE HAND

energy in this task and accomplished some excellent results Various centers were established in Army hospitals throughout the country and to these patients with hand injuries were funnelled after their return from overseas In each installation Bunnell undertook the tremendous task of training by precept and example young surgeons in the reconstructive procedures and technic of hand surgery It was a huge job well done and gave a significant impetus to the development of hand surgery throughout the country The young men whom he trained, along with certain others long interested in this field, formed the nucleus for the development of the American Society for Surgery of the Hand Similar organizations in England and Sweden, and a special division in the French Society of Plastic Surgeons attest to the world-wide interest in surgery of the hand From a somewhat neglected field, turned over to the most junior man on the service, it now demands the attention of some of our best surgeons "

The progress of surgery of the hand is based on the improvement and refinement of older methods and the introduction of new and valuable therapeutic adjuncts Of the pioneers in this field, those particularly to be mentioned are Kanavel, Bunnell, Koch, Mason, Mayer, Lexer, and Iselin The author has referred to them extensively, and wishes to acknowledge his indebtedness for their invaluable help

The general principles of reparative surgery of the hand do not differ from those applied to other parts of the extremities, but since the hand is the most useful member of the body, those principles need amplification and specification

The following chapters are based on anatomical units like the former ones, namely, the skin, subcutaneous tissue, and the fasciae, the muscles, tendons, nerves, and blood vessels, and the bones and joints In addition, there are discussions of the hand in toto (neoplasty of fingers, cineplasty, and congenital deformities)

XXVII

INTRODUCTORY ASPECTS OF THE HAND

Our present time sometimes called the "mechanized age accounts for a great number of injuries and infections of the hand It is estimated that in industry more than one third of all accidents involve the hands. Loss of parts or of the whole hand either actual or functional means in the majority of cases a decrease in the earning capacity of the victim Hence the responsibility of the surgeon who takes care of a patient with an injured or infected hand is great. Unfortunately it is not uncommon that many lesions of the hand are treated by young, surgically inexperienced physicians often an intern sutures a lacerated tendon in an inadequately equipped Out Patient Department without any assistance and with results which are far from satisfactory or a fresh surface defect is left to granulate with the result that possible reconstruction is delayed while immediate transfer of a graft or flap would have saved the patient valuable time Again an infection may be opened inadequately or with a wrong incision resulting in extension of the infection and possible loss of function. These are only a few examples demonstrating the consequences resulting from inexperienced surgery

A great impetus to the development of hand surgery was brought about by World War II In his stimulating and vividly written survey of fifty years progress in surgery of the hand Michael L. Mason of Chicago summed up by saying

At the beginning of the second World War the Surgeon General (Kirk) requested Sterling Bunnell to supervise the handling of hand surgery in the Army Bunnell expended a great amount of time and

derm, G-11, solution Gauze pads—not brushes—are used for scrubbing. The wound is constantly protected by the sterile gauze pad during the cleansing The scrubbing is performed for ten minutes, by the clock. With dirty and greasy skin, the scrubbing is performed for twenty minutes The skin is then washed with saline solution, and Surgeon B rescrubs Irrigation of the wound is now performed by Surgeon A The injured part is placed on a sterile modified Bryant irrigating pan, so that irrigation may be performed under sterile conditions From 2 to 20 liters of isotonic saline solution is used, depending upon the type, location, size, depth, and contamination of the wound Surgeon A rescrubs. The skin from elbow to fingertips is now prepared by Surgeon B, with ether and aqueous Zephiran. Colored solutions are never used The wound is protected with a sterile gauze pad so that no chemical enters the wound. The wound is draped, and Surgeon B rescrubs Débridement and reconstruction are then performed

General or local anesthesia may be used, depending upon the size and extent of the wound. In many cases, a pneumatic tourniquet must be applied (see p 716)

The therapeutical principles as applied to wounds of the hand are the same as those for other wounds (p 104), and can be summarized· converting the contaminated wound into a clean wound, primary closure of the wound, if it is treated within the first twelve hours, open surgical drainage, if the wound is treated later, followed by secondary closure on the fourth day (see p 107) The contaminated wound is changed into a clean wound by thorough cleansing of the surrounding area with soap, water, and alcohol, and by excision of the ragged wound edges and of devitalized tissue, tissue that can be preserved should not be sacrificed This is particularly true in wounds with avulsion of skin if the skin flap is viable The wound is closed with a few interrupted sutures If large parts of skin have had to be sacrified or are missing, the defect is primarily covered by skin-sliding or by skin transplants, as described later. If the wound is infected, it is only débrided and not excised, and open surgical drainage is applied, as outlined in greater detail on p 112 Hyaluronidase, which tends to prevent swelling, is injected subcutaneously 150 units for each finger, 300 units for the base of the thumb and as high as 800 units for the palm In either case, a moderate pressure dressing is applied, and the extremity is splinted with the wrist in cocked-up position, the fingers in semiflexion, and the thumb in semiflexion, abduction, and opposition A useful splint for this purpose is the simple universal hand splint developed by Mason and Allen. Flat splinting of the hand or any of the digits

XXVIII

SKIN, SUBCUTANEOUS TISSUE, AND THE FASCIAE

Defects

IN THE majority of cases, defects are accidental less often due to pathological conditions such as tumors.

WOUNDS

The treatment of wounds has been described in detail on p 104 Following injuries the hand is particularly susceptible to the development of complications leading to serious disability For this reason it is important to protect the freshly injured hand most carefully against such complications as infection additional tissue damage and stiffening This protection is best afforded by noninterference with the wound cleanliness of the surrounding areas and the application of sterile protective dressings The definitive treatment of an open hand injury should be performed only if adequate facilities for the purpose are available such as aseptic surgical technic, adequate anesthesia proper instruments sufficient assistants, good lighting and a bloodless operative field A proper evaluation of the extent of the injury should be made at this stage After this is done and while the wound remains covered with sterile compresses a wide area is given a thorough cleansing consisting of shaving and then scrubbing with soap and water Flynn's procedure is as follows

Two surgeons are scrubbed The dressing is removed and the wound covered by a sterile gauze pad Surgeon A with gloved hands shaves the injured extremity from elbow to fingertips He then rescrubs A new sterile gauze pad is now placed over the wound and Surgeon B with gloved hands scrubs the extremity from elbow to fingertips with a pHiso-

leaving a bloodstained pattern on it A flap of suitable width and length is now outlined with an aniline dye The flap is constructed so that the pedicle comes to lie proximally The important creases of the hand should not be crossed The donor area is now anesthetized, and the flap containing a sufficient amount of subcutaneous fat tissue is raised After hemostasis, the injured finger is bent and the peripheral end of the flap sutured to the dorsal wound edge of the finger, that is, to the nail bed and also to the lateral edges (Case 128, p 1024) If a long flap is required, the circulation may be insufficient, hence, transfer of the flap should be delayed for one week by returning the flap to its original site (In the vast majority of cases, delaying is not necessary since the blood supply is abundant, however, a sufficient amount of subcutaneous fat must be left on the flap) After the flap is sutured to the finger, the finger is immobilized with adhesive strips, which are passed through an alcohol flame (Case 128, p. 1024). The underlying wound is covered with petrolatum gauze, a gauze dressing is applied over the immobilized finger, leaving the other fingers free. The wound is inspected two days later, the immobilizing adhesive strips may need reinforcement Ten days after the operation, the adhesive strips are removed, and the base of the flap is incised from each side under local anesthesia, thus narrowing the pedicle This step is followed by reapplication of the adhesive strips On the twelfth postoperative day, the pedicle is severed completely, and the flap is adjusted to the finger on the fourteenth day. This is done by means of a wedge-shaped excision of the raw surface of flap and finger and suturing the wound edges The raw area at the palm is left to granulate and heals quickly. In none of the author's cases did this area require skin-grafting or skin-sliding

If the defect involves the volar surface of the terminal phalanx, the flap is constructed so that it opens up laterad or mediad Such a flap may also be used for small volar defects of the middle phalanx In some cases in which the palmar flap is not applicable, the cross-finger flap may be possible (Cronin) (see below) The cross-finger flap is also suitable for amputation stumps at any level This subject has been thoroughly discussed by Tempest, by Horn, and by Curtis

LARGE DEFECTS OF DORSAL OR VOLAR OF FINC

The indications for a graft or a ... men ... fo
going, that is, a thick split graft is ... tend ... dc
without tendon sheath) and no ... . If

must be avoided at all times. The arm is elevated either on a pillow or in a sling Tetanus antitoxin and antibiotics are administered

For complicated compound wounds the treatment should be preceded by a diagnosis and estimation of injuries to important structures Those injured should be treated accordingly, as outlined later under the appropriate headings

If a wound has resulted in a defect of the covering tissue, the defect should be covered with a skin graft or a pedunculated flap immediately following excision of dead tissue, unless the wound is grossly infected. This procedure not only shortens the healing period, but also counteracts functional disabilities and deformities If the defect is left to granulate, scar tissue will develop which may cause irreparable damage Indications for the use of the different types of skin transplants are outlined in the following discussions.

BURNS

For treatment of burns see p 134 For proper splinting see p 690 (See Case 134 p 1034)

DEFECTS OF FINGERTIPS

This very frequent injury is often treated expectantly, in the hope that the wound will granulate and heal. If the defect is only superficial not exposing the phalanx, the resulting scar may be of good quality Nevertheless the healing process is much shortened and the surface more adequately protected if primarily covered with a skin graft (Reed and Harcourt, McCarroll Sternberg) In those traumatic defects which result in exposure of the bone, Gatewood and Jones recommend the transfer of a flap from the palm a simple and highly effective procedure It provides skin which is similar to that lost. The cosmetic effect in one of the author's patients was such that the site of the former injury escaped the scrutinizing eyes of three medical examiners It provides an adequate padding: it shortens the healing period it makes amputation of the phalanx unnecessary

Technic: The hand is prepared in the usual way and the finger is anesthetized by blocking the digital nerves at the proximal phalanx Procaine 2 per cent, is used without epinephrine (The latter may cause gangrene of the finger) The devitalized tissue is excised. *If bone is not exposed*, the defect is covered with a full thickness graft which is taken from the cubital region of the elbow joint of the same side. The graft is sutured in place The sutures are left long a small pad of mechanic's waste is applied and the sutures are knotted over the pad If bone is exposed, the finger is bent so that the defect touches the palm

exposed a free graft will not take Hence the defect must be covered with a flap.

If possible a flap from the immediate neighborhood should be raised. Several useful methods are available notably the sliding flap from the same finger (Lewin), and the cross-finger flap (Cronin) These methods are mainly applicable to defects on the volar surface of the finger This subject has been thoroughly discussed by Tempest, by Horn and by Curtis Lewin elevates a single-pedicle flap (pedicled proximally) from the dorsolateral finger surface a layer of soft tissue should be left behind to cover the neurovascular bundle and the dorsal aponeurosis The flap is rotated into the defect and the resulting secondary defect covered with a full thickness graft.

A more versatile method is the cross-finger flap (Cronin) For example a defect of the volar side of the index finger is covered with a flap which is raised from the dorsoradial side of the third finger and pedicled volarward without injuring the digital vessels and nerves. It is hinged volarward and sutured into the defect of the index finger The donor area at the third finger is skin-grafted The flap can usually be transplanted without delayed stages. A light plaster splint is used for immobilization The flap is gradually severed from its pedicle after from twelve to seventeen days.

For dorsal defects if local flaps cannot be used the pocket flap from the abdomen is recommended (p 76 Cases 127 131 pp 1023 1030) For volar defects, a single-pedicle flap can be constructed from the same or the opposite side of the abdomen (Cases 129 133 pp 1026 1033) The flap should be cut as thinly as possible without however endangering its blood supply The donor site can be closed primarily by undercutting the wound edges and by skin shifting To counteract shrinkage the flap should be made one third larger than required

Another donor area to be recommended is the forearm or upper arm of the opposite side. The injured hand is laid upon the opposite arm and both immobilized. Closing of the donor site and the need to counteract shrinkage are the same as just described for the single-pedicle abdominal flap Reid McCash and others have demonstrated the versatility of this technic. If the forearm must be held strongly supinated a heavy Kirschner wire is drilled into radius and ulna and left in place until the flap is severed from its pedicle (Howard quoted by Bunnell)

LARGE DEFECTS OF DORSAL OR VOLAR SURFACE OF HAND

The causes of large surface defects of the hand are manifold. Crushing injuries avulsion of the skin and severe burns are the common causes

transfer of the flap If the pedicle of the flap can be made broad—and this can be done often—the flap can be transferred immediately If the pedicle must be narrow, transfer must be delayed (see p. 70) If delaying becomes necessary in a traumatic defect the wound of the hand is covered with sterile dressings a moderate pressure dressing and a splint are applied. If there is no evidence of infection the dressing is left in place for five days. It is then changed and the arm placed in a warm hand bath and active finger exercises are instituted while the hand is in the water This process should be repeated every other day and the splint reapplied each time Whenever the flap is ready for transfer (for details see p. 73) it is raised and if the circulation remains adequate it is transferred. Prior to the transfer of the flap however the abdominal donor wound is skin grafted. If the flap is still too bulky more fat is excised from its raw surface. The flap is now sutured to the defect of the hand, after the granulations of the wound have been sliced down to their yellow vascular base The suturing should be done as accurately as possible, particularly if the webs between the fingers need covering Immobilization and after treatment are the same as described on p 71 (Cases 130 131 140 pp *1028 1030 1040*)

Deformities

CICATRICIAL CONTRACTURES

Cicatricial contractures are more often due to burns than infections They present some of the most difficult problems in reconstructive surgery These problems increase with the depth of the scar While in other parts of the body a second-degree burn as a rule, does not cause any functional damage in the hand, particularly at the dorsum it is quite frequently followed by severe contractures. In a second-degree burn the deep layer of skin remains undamaged Ordinarily epithelium regenerates from this area and covers the raw surface Occasionally in the hand, however particularly at the dorsum the deep layer of skin does not regenerate epithelium but develops an irregular hypertrophic or keloid like contracting scar Infection plays a role but even without infection such a scar can develop The contracture of the skin soon causes a secondary contracture of the deep fascia tendon joint capsules and ligaments Of these structures the contractures of the *collateral ligaments* of the metacarpophalangeal joints are most disastrous. When the metacarpophalangeal joints are in extension or hyperextension the collateral ligaments are maximally relaxed. Prolonged immobili

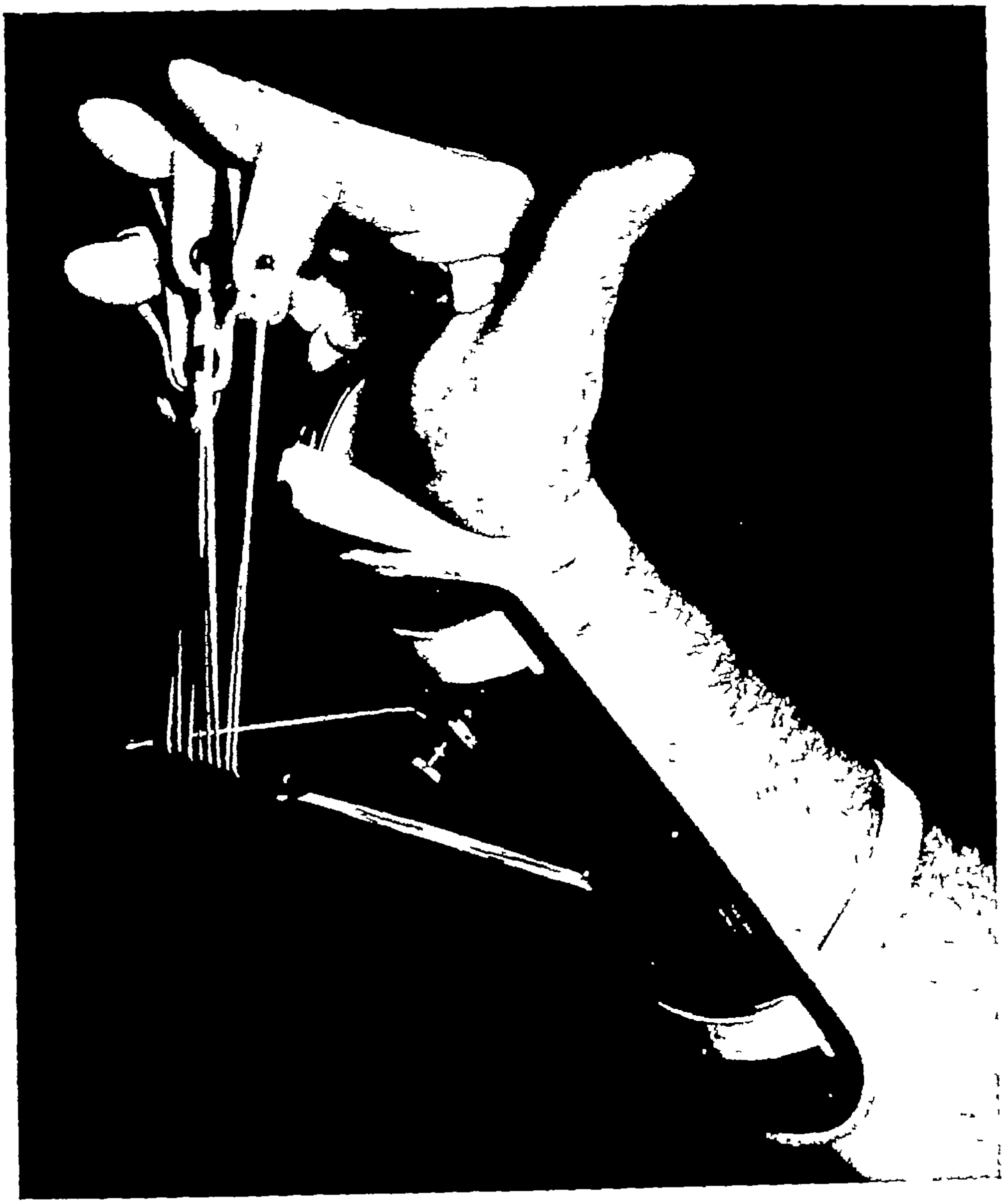

Fig 365 Cock-up splint of flat spring steel or piano wire for dorsal flexion of wrist It has an outrigger over which metal tube is slipped to act as roller Outrigger gives desired direction of pull of rubbers to fingers (Bunnell)

long extensor and the interosseous muscles By moving the joint, the thickened collateral ligaments are found The ulnar one is then completely excised, the radial ligament may be left behind (p 745) However, the capsule of the joint should not be incised, particularly not transversely, since this would lead to subluxation of the joint Fowler pointed out a few obstacles that may still be in the way of joint rotation If by flexing the proximal phalanx the interphalangeal joints extend, this is an indication that the extensor tendon is caught in scar tissue, and this must be corrected If the joint opens like a book, instead of the phalanx gliding around the meta-

The principle in correcting these contractures consists in excision of the entire scar reduction of the contracture and closure of the defect with a graft or a flap It has been the experience of a number of surgeons (Blair Brown Koch Garlock Padgett MacCollum Conway, Dufourmentel Tierny Kröner Greeley, May) that grafts can more often be used than previously thought possible. Brown states that grafts have given satisfactory results in a high percentage of patients and in many where the use of a pedicle flap might have been thought necessary The application of a skin graft may require more time at one operation but the total amount of work may be much less A free graft however, can be used only if the tendons bones, and joints do not need to be exposed If they must be exposed or need later reconstruction the transfer of a flap is the only choice (Case 140 p. 1040)

Technic (Contracture of Dorsum of Hand) (Cases 135 136 pp 1035 1036) The operation is performed under general anesthesia the operating field prepared in the usual way with soap water, and alcohol and a blood pressure cuff inflated to obtain a bloodless field (see p 716) The entire scar is outlined with an incision it is important that every bit of scar tissue should be removed, and hence that the outlining incision should run within normal tissue At the finger webs the incision must usually be carried to the flexor side.

The depth of the incision depends upon the depth of the scar tissue As explained previously, in a second-degree burn the cicatricial changes involve mostly the skin Hence the incision should penetrate just through the skin and reach the space between the skin and superficial fascia The subcutaneous veins are in this space care should be taken not to injure them Excision of the cicatricial skin is performed at the level of the veins (Case 135 p 1035) In third-degree burns in which the superficial fascia is destroyed and replaced by scar tissue excision of the scar tissue is performed at the level of the deeper structures but care should be taken not to expose the tendons if the use of a free skin graft is considered To avoid exposure of the tendons the scar tissue over the tendons is removed in layers, and the tendon is gradually stretched by cross-cutting the covering tissue in numerous places until full flexion can be reached. If the collateral ligaments of the metacarpophalangeal joints are contracted and have caused hyperextension fixed deformity of the metacarpophalangeal joints it is most difficult to overcome the contracture merely by simple stretching Invariably the ligaments have to be severed from their insertion at the metacarpal heads. This is best done according to the technic of Bunnell The tendon of the interosseous muscle is identified and retracted away exposing the joint capsule between the tendons of the

The defect is now covered with a thick split or full-thickness graft. If properly removed and applied, either one will give equally good results The author uses a thick split graft removed with the dermatome. Its application is simpler, and it takes quicker, hence, motion exercises can be started earlier The entire sheet of graft is laid upon the raw surface Between the fingers, the graft is incised longitudinally with straight scissors, thus, individual extensions are formed for each finger and finger web The graft is now sutured in place as accurately as possible, then follows the usual pressure dressing.

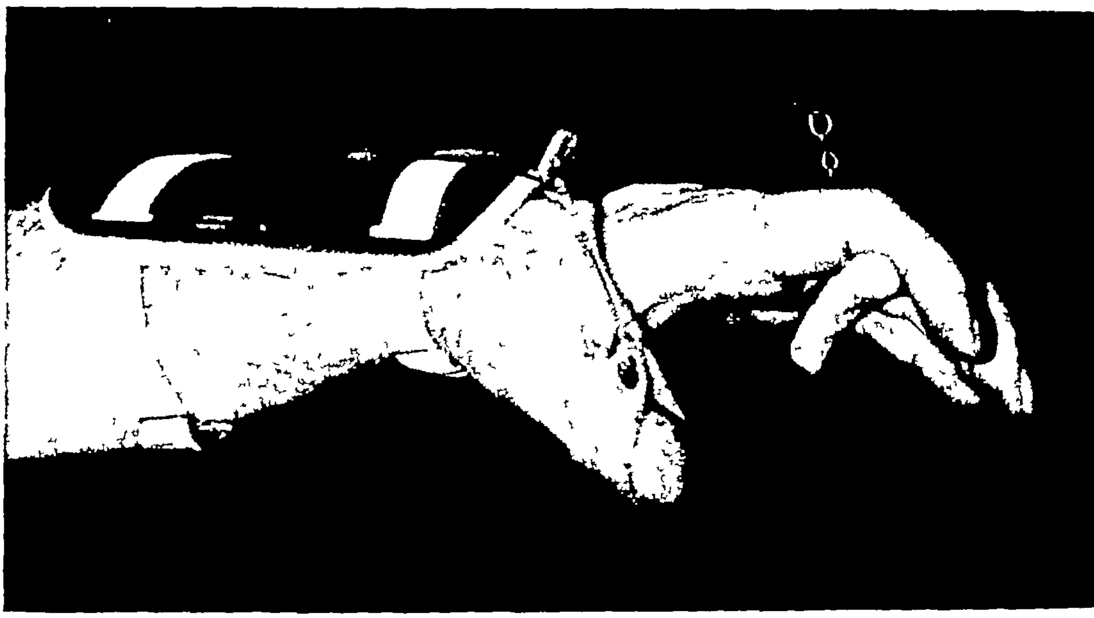

Fig 367 Splint for radial palsy (Thomas) to furnish muscle balance. Spring wire which holds thumb is very light.

If the contracture cannot be overcome without wide exposure of the tendons, then the following possibilities of repair are available. Either one proceeds with excision of the cicatricial tissue as far as possible without exposure of tendons and covers the defect with a skin graft and plans subsequent similar repair work (such gradual repair work is particularly advisable where the tendons have been found too tight), or, if tendons or deeper structures must be exposed, the transfer of a flap becomes necessary (Case 140, p 1040)

In those cases in which the clawing of the fingers is mainly due to contracture of the ligamentous structures and less due to contracture of the skin, repair is best performed according to Howard's method (quoted by Bunnell) A longitudinal incision is made over the dorsum of the knuckle (If the skin is also tight from contracture, a transverse incision

carpal head the base of the phalanx is being blocked by adhesion of the anterior capsule to the metacarpal head. If this is the case the anterior capsule should be explored and reflected from the metacarpal head with a probe or dual elevator If the dissection lasts longer than ninety minutes the blood pressure cuffs should be deflated temporarily and then reinflated After dissection is completed the blood pressure cuff is deflated and thorough hemostasis instituted After this the cuff is reinflated

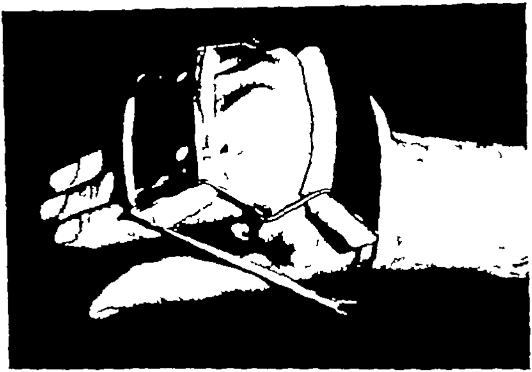

Fig. 366. Knuckle-bender (Bunnell) To flex and exercise proximal joints of fingers. *Splint* has three padded points of pressure activated by rubber bands, with pivots corresponding to axes of joint. Rubber on back of thumb helps to oppose it.

The volar side of the forearm and hand is now placed on a *sterile* well padded splint (wire mesh splint or aluminum) The splint is bent until the fingers are in flexion The wrist is slightly extended The arm *is immobilized* on the splint by bandaging the wrist. The fingers are kept in flexion and abduction either by simple bandaging or by *wire traction* applied through the bone of the terminal phalanx the wires are fastened to the end of the splint (compare with Fig 369) The *simplest* way of applying wire traction through the bone of the terminal phalanx is as follows A thin Kirschner wire is *drilled through* the bone and cut rubber bands or thin stainless steel wires are fastened *to the ends* of the Kirschner wire the ends of the latter are bent acutely to prevent slipping of the elastic bands or wires

splint Nearly all of them can be readily made in the hospital workshop Bruner has added valuable information

If the contracture is unyielding, forced motion may be attempted under anesthesia and the gained improvement in position maintained until the traumatic reaction is over

Alternative Method If a flap instead of a graft is to be used, the method of covering the defect is similar to that described on p 73

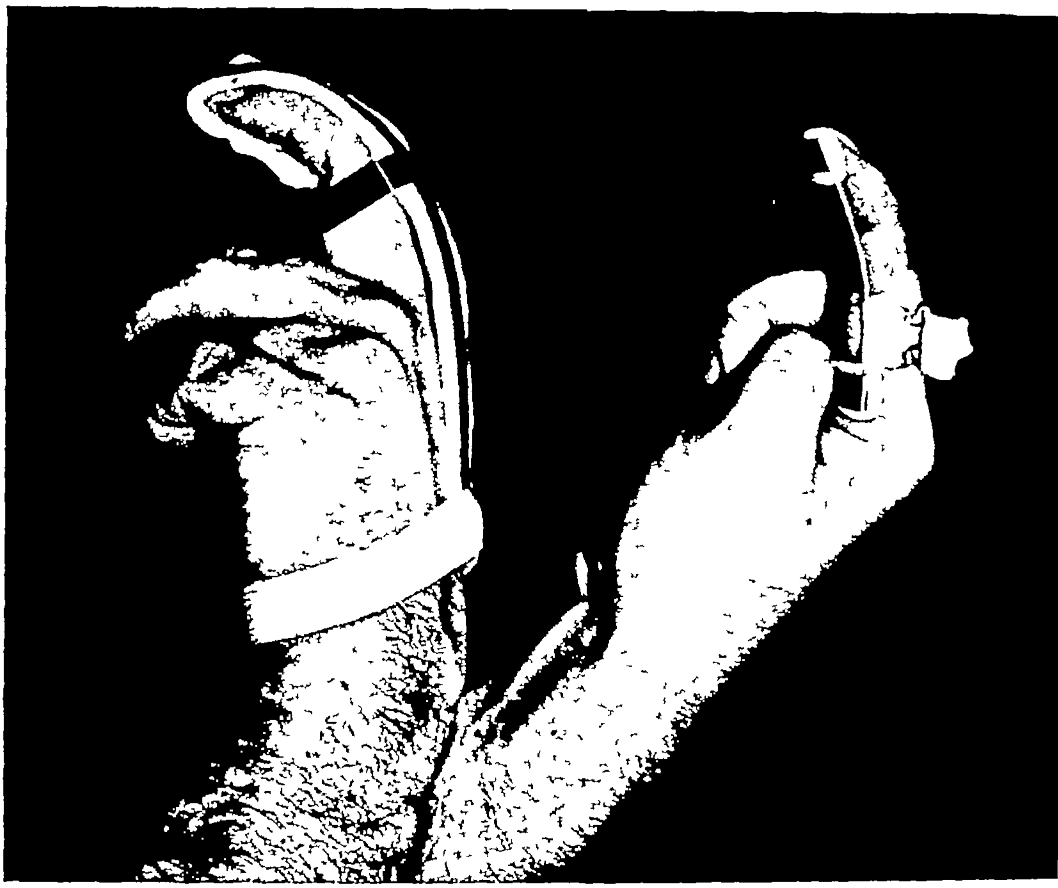

Fig 368, *Left* Simple splint of clock spring to extend fingers *Right* Safety-pin splint of spring wire to straighten fingers

Technic (Contractures of Volar Surface of Hand): The procedure is similar to that described for contractures of the dorsum. The dissection is more difficult than on the dorsal side, particularly at the side of the fingers Great care must be exercised not to injure the digital vessels and nerves. Stretching of the fingers should be cautious and gradual, cross-cutting the covering of the tendons and separating the lateral ligaments of the interphalangeal joint facilitate stretching After completion of the dissection and hemostasis, the arm is placed on a sterile well-padded wooden splint. The places where the knuckles and the inter-

is made just behind the knuckles.) The long extensor tendon is split longitudinally and retracted The joint capsule and the collateral ligament on each side of the joint are exposed The ulnar collateral ligament is now completely excised with pointed scissors Excision of the radial collateral ligament may not be necessary (p 745) As pointed out above, the anterior pouch of the joint may be obliterated by adhesion of the capsule to the anterior part of the metacarpal head preventing full flexion of this joint. Restoration of the pouch is now performed (see p 692) The split extensor tendon is sutured with fine silk followed by suturing of the skin (In cases of skin shortening in which a transverse incision was made a gap will result after flexion of the finger which must be skin-grafted) (For contractures of the intrinsic system see p 744)

After Treatment Dressings and sutures are removed ten days after the operation The pressure dressing is reapplied and should remain applied for another eleven days. Dressings, splint and traction wires are then removed If the pressure dressing is removed too early particularly if motility is allowed prematurely an acute swelling of the hand may occur causing a delay or uncertainty of return of function

Particularly valuable are composition exercises tying of knots double motions such as gripping a square mallet handle and using the mallet pressing spring plungers turning square or round headed screws against elastic resistance cutting with spring scissors An intriguing method of homework is the use of the so-called Bouncing Putty which is an elastic plastic material it usually fascinates the patient thus stimulating his digital activity *

In a number of cases however splints must be reapplied between the exercises to prevent recurrence of the contracture. Some of these splints must be especially constructed with incorporation of elastic appliances to hold the tissues on a mild stretch until they grow longer These appliances should not cause pain and should be easily adjustable An ingenious innovation is the so-called "active splinting of the hand as introduced by Bunnell He found that a spring or elastic splinting is more efficient than unyielding splinting Rigid splinting makes rigid hands. In splinting with springs or elastic, the joints are never strained to excess nor are they immobilized Active splinting is physiological splinting The hands work continuously against the spring or elastic and with these springs they are usually exercised Bunnell states "By this system you splint to mobilize not to immobilize It is functional splinting" (Figs. 365–368) Peacock has demonstrated many varieties of this sort of

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* The Bouncing Putty is made by General Electric Company and distributed by S. R. Gittens, 1620 Callowhill Street, Philadelphia 30 Pa.

The after-treatment is similar to that described on p 695

Alternative Method If a flap instead of a graft is to be used, the method of covering the defect is similar to that described on p 73

Technic (Contracture of Thumb): Adduction contracture of the thumb may not only cripple the action of the thumb but also block flexion of the fingers If the contracture involves the skin only, a vertical relaxation incision is made through the contracted web This incision, however, should be made sufficiently deep toward palm and dorsum of the hand to make the resulting dorsal and volar scar V-shaped, thus counteracting recontracture The contracture is then released by abducting the thumb, and the raw surface is skin-grafted Deeper contractures, however, require excision of all deep contracted structures, i e, first dorsal interosseous muscle and part of the adductor and palmar fascia Closure of the raw surface in such a case invariably requires transfer of an abdominal flap While the flap or graft is healing, abduction of the thumb can be temporarily maintained with a bent Kirschner wire drilled through the dorsal surface of the first and second metacarpal bones or by a unit of the Roger-Anderson extraskeletal fixation splint (see p 422) In rarer cases, in which abduction is difficult to maintain, transplantation of a bone strut may be subsequently required (see p 758) (Case 139, p 1039)

CONTRACTURE OF PALMAR APONEUROSIS (DUPUYTREN'S CONTRACTURE)

Contracture of the palmar aponeurosis, known as "Dupuytren's contracture," must be classed among diseases of unknown origin, in spite of many attempts to explain it (Ross and Annan) Contributing factors, such as trauma and a curious association between Dupuytren's contracture and epilepsy, must be mentioned (Lund, Skoog) A congenital predisposition is also unquestionable The disease progresses gradually, involving not only the palmar part of the aponeurosis but its extensions to the fourth and fifth fingers, less often those of the other fingers, very rarely the thumb The superficial palmar fascia (see Fig 324) is the continuation of the palmaris longus muscle It fans triangularly across the palm with extension into the fingers, forming the superficial digital fascia The entire aponeurosis consists of longitudinal bands, which in the palm are connected with each other by transverse bands (*17* and *19* in Fig 324) In the palm, innumerable minute fibrous fasciculi extend from the palmar aponeurosis to the skin These hold the skin close to the underlying palmar aponeurosis, permitting comparatively little sliding movement of one upon the other These thread-like fibrous strands divide the subcutaneous fat into small, irregular masses Numerous minute blood

phalangeal joint come to lie should be particularly well padded (with rubber sponge) to avoid pressure ulcers and exposure of the dorsal joint surface Hand and fingers are fastened as previously described.

If a skin graft can be used to cover the raw surface, and it can be in the majority of cases a thick split graft or full thickness graft is available The author has used both with equally good results. The application of the thick split graft is simpler The technic of application has been described (Fig 369)

Fig 369 Way of immobilizing hand and fingers after release of contractures. This child had cicatricial contracture of all fingers. Contracting scar was excised, denuding palm and volar surface of fingers. Contracted tendons were stretched without opening tendon sheaths. Hand was placed on sterile well-padded wooden splint. Forearm and wrist were bandaged to splint. Wire traction was applied through bone of each finger (p. 693) The wires were fastened to end of splint, keeping fingers in extension and abduction. Thumb was held against bandage roll in abduction. Raw surface was then skin-grafted Figure depicts hand ten days after operation following removal of first dressing and of sutures. Graft took well.

administration of vitamin E (Stenberg, King), are disappointing, as the author can state from personal experience. Baxter et al. and Zachariae et al recommended cortisone treatment. For the vast majority of the patients, operation is the method of choice and should be performed before the contracture has caused serious dysfunction or ankylosis of the fingers Surgery, however, must be adequately performed Insufficient removal of the diseased structures invites recurrence The peculiar pathological process is not confined to the palmar fascia, although this is the primary seat. The nodules and the shrinkage of the skin over the diseased fascia and the not infrequent recurrence of the contracture in the skin, even after thorough removal of the underlying fascia, are definite proof of this statement These findings led Lexer to remove not only the entire fascia, but also the involved skin Macroscopic and microscopic examinations of removed specimens clearly reveal that the palmar fascia is intimately connected with the skin and also with the underlying tendons and tendon sheaths by dense fascial extensions Only after complete removal of fascia and fascial extensions can recovery be expected, [illegible] return of good function. The operation is tedious, and should [illegible] be performed with the tourniquet applied Most aspects of this [illegible] have been thoroughly treated by Tanzer and by Skoog in his [illegible] monograph.

Technic (Lexer) (Figs 370–372) (Cases 141, 142, pp 1042, 1044) · [illegible] usual aseptic preparation, a blood-pressure cuff is inflated to [illegible] bloodless field (p. 716) The incision starts over the origin of [illegible] fascia proceeds along the main longitudinal palmar crease, [illegible] transverse creases at the radial side of the palm, and ends over [illegible] of the base of the index finger The diseased part of the [illegible] circumscribed by another incision, while a small transverse [illegible] at the ulnar side to facilitate exposure (Seldom is it [illegible] the diseased skin behind, except in the early stage be[illegible] has developed). The skin and subcutaneous tissue of the [illegible] thenar region are now dissected away from the palmar [illegible] and distal [illegible] done with the healthy skin of th[illegible] e are [illegible] Thus, four flaps of skin and sub[illegible] entire palmar [illegible] on [illegible]

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vessels pass through this subcutaneous tissue to the derma In Dupuytren s contracture hypertrophy and hyperplasia of this fibrous tissue result in ultimate displacement of the fat masses and partial obliteration of the blood vessels thereby interfering markedly with the nutrition of the skin Obviously this points to the wisdom of early surgical excision of the palmar aponeurosis in Dupuytren s contracture In the distal part

Fig. 370: Repair of Dupuytren s contracture of palmar aponeurosis (Lexer) Incision starts over region of palmar fascia, proceeds along main longitudinal crease crosses transverse creases at radial side of palm, and ends over radial side of index finger The diseased part of skin is circumscribed by another incision while small transverse incision is added at ulnar side.

of the palm septa extend from the deep aspect of the palmar aponeurosis to the deep transverse palmar ligament forming the sides of annular fibrous canals for the passage of the ensheathed flexor tendons and lumbrical muscles as well as of the blood vessels and nerves. If these septa are contracted they may interfere with the proper function of the fingers

In the majority of cases the disease is recognized late and quite often treated inadequately Nonoperative treatments such as irradiation or

dominal flap becomes advisable, since a free graft will not survive on poorly vascularized structures such as naked tendons (see p 73) A good method is the sliding-flap procedure of von Seemen According to this technic, a single-pedicle flap—the pedicle placed proximally in the ulnar-palmar-dorsal region of the wrist—is mobilized from the hypothenar and dorsal region of the hand The peripheral end of the flap is

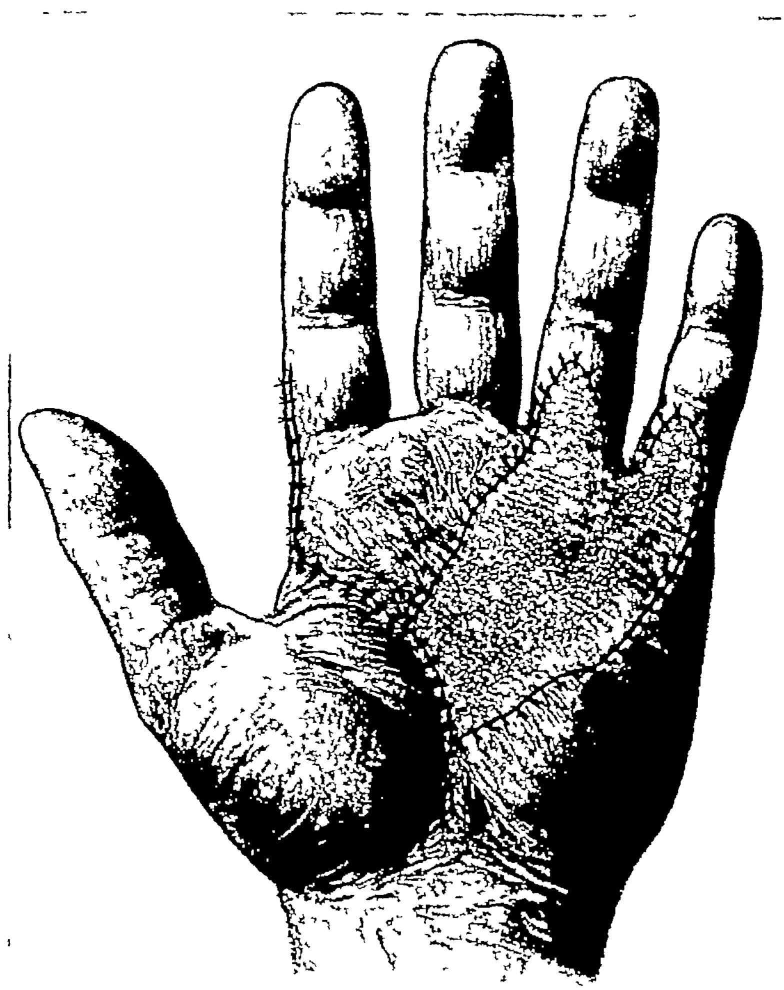

Fig 372 The skin flaps are returned and defects covered with full-thickness graft

at the palmar and dorsal base of the fifth (or fourth and fifth) finger The flap is well mobilized, care being taken that the gliding tissue over the extensor tendons on the dorsum of the hand is not injured The flap is now rotated into the palmar defect, and the secondary defect over the dorsum of the hand is covered with a thick split skin graft

After-Treatment The dressing is changed on the eighth postoperative day. The splint is temporarily removed two weeks after the operation From then on, the treatment is similar to that described on p 695

and tendon sheaths, and also the diseased skin island The dissection is tedious and should be carried out with great care to avoid injury to the digital nerves and vessels. The tendon sheaths should not be opened

The blood pressure cuff is now deflated Obtaining thorough hemostasis is the next step The blood pressure cuff is reinflated and remains in place until the pressure dressing is applied Forearm hand and fingers

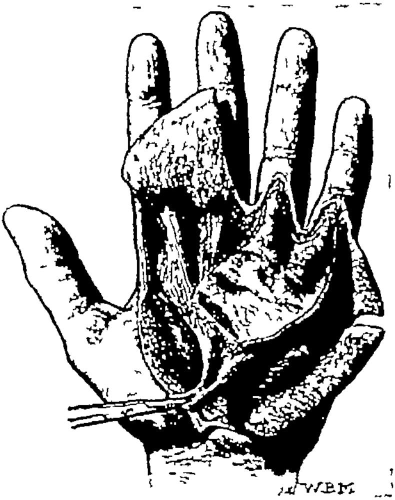

Fig. 371: Skin and subcutaneous tissue of thenar and hypothenar region are dissected away from palmar fascia. Same is done with healthy skin of radial and distal parts of palm. The four skin flaps are reflected, exposing entire palmar fascia and leaving islandlike diseased part of skin in connection with fascia. Palmar fascia is severed from tendon and entirely excised. Dotted line indicates distal lines of excision.

are immobilized in a previously prepared well padded splint The four skin flaps are returned The defect left from excision of the diseased skin is covered with a full thickness or thick split skin graft The usual pressure dressing is now applied

If the excision should have resulted in wide exposure of the tendons which can be avoided in most cases closure of the defect with an ab-

structures is inadvisable if the two fingers function effectively as one and the severance would result in loss of function of one.

Technic (Case 143, p 1045) The fusion between two fingers is severed longitudinally without injury to the digital arteries and nerves The dorsal and volar longitudinal incisions, however, should not be made straight, but Z- or S-shaped, as recommended by J Webster and others to counteract secondary contractures along the scars The separation should be carried as proximally as possible until the division of the digital arteries is reached on the volar side, while on the dorsal side the separation should reach even farther proximally Thus, the floor of the web is oblique, its obliquity sloping from palm to dorsum After complete hemostasis, a full-thickness graft is removed and cut according to pattern and applied as accurately as possible The commissure at the base of the finger should be well covered, keeping in mind its obliquity A pressure dressing is now applied, with incorporation of mechanic's waste cotton between the fingers, followed by immobilization

Alternative Method (Case 144, p 1046) In cases in which the fused portion of the skin at the base of the web is redundant, a dorsal triangular flap of skin and subcutaneous tissue can be formed—after the suggestion of Zeller—to cover the floor of the commissure The base of the flap is at the level of the metacarpophalangeal joints, its tip at the level of the proximal interphalangeal joint The fusion is then severed as described The flap is now laid upon the floor of the cleft between the fingers and its tip sutured to the skin of the volar side The remaining raw surfaces are covered with skin grafts as previously described

After-Treatment Splint, dressing, and sutures are removed eight days after operation From the tenth day on, the dressings are changed daily, the hand is placed in a warm hand bath, and active finger motions are instituted.

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SYNDACTYLISM

Syndactylism is a deformity which shows hereditary tendencies and association with other congenital deformities (Murphy Snedecor) It occurs in various forms and degrees from the simple web of skin joining the fingers to the fibrous or complete cartilaginous or osseous fusion In the latter case fused tendons tendon sheaths digital vessels and nerves may also be found Fused fingers can be severed only by operation The question arises When is the best time to operate? If the operation is performed early in life the newly formed web has a tendency to move distally with the growth of the fingers The chances are that another operation must be performed later Hence the operation should not be performed before the age of six possibly later The only indication for early operation is if the deformity should cause a distortion or contracture of the joints.

Another question which arises is What type of operation should be performed? There are a number of cleverly devised methods which aim to sever the skin between the fingers in such a way as to establish local flaps with which to cover the raw surfaces. For all practical purposes however one can safely say that none of these procedures is adequate some may even be harmful One exception however is that of Zeller (Case 144 p 1016) which in incomplete cases may be applicable. The reason is that after the fingers are severed the raw surfaces are so large that there is not enough local tissue available to close the defects Any attempt to stretch the available tissue will inevitably lead to skin necrosis The resulting scar tissue may cause distortion and contracture of the fingers which is exceedingly difficult to overcome even if operated on again The aim of the operation is to sever the interdigital fusion sufficiently to permit normal abduction of the fingers and to cover all raw surfaces with normal covering tissue Kanavel in his outstanding monograph Congenital Malformations of the Hand emphasizes that digital vessels and nerves should not be injured that two sides of the *same finger* should not be operated upon at the same sitting It may happen *particularly* in more extensive cases that two fingers along their fused portion are supplied by only one digital artery *Hence if in complete syndactylism* all fingers were severed at the same time *partial or complete* necrosis of some or all of the fingers may result. Hence the fusion between thumb and index finger and third and fourth fingers can be safely severed in one sitting After establishment of a *sufficient collateral* circulation (several months later) the remaining fused parts between the index third fourth and fifth fingers are severed In those extensive cases in which bones joints, and tendons are fused severance of the fused

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and the nervus medianus with its digital branches beneath it The middle layer contains the tendons of the long flexor muscles, their gliding structures, and the musculi lumbricales The latter originate from the deep flexor tendons The deep part of the space contains the arcus volaris profundus, which, in contradistinction to the superficial arcus, is formed by a strong branch of the arteria radialis and a small branch of the arteria ulnaris It also contains the deep branch of the nervus ulnaris

Hypothenar Space (Figs 374, 375) This embodies the three short muscles of the fifth finger the musculus abductor digiti quinti, flexor digiti quinti, and opponens digiti quinti, it also contains the strong ramus superficialis of the arteria ulnaris (for the formation of the arcus volaris superficialis) and the ramus superficialis of the nervus ulnaris The deep branches of the same artery and nerve are deeply embedded between the short abductor and flexor muscles of the fifth finger

FLEXOR TENDONS AND MUSCLES

The flexor tendons of the five fingers enter the deep volar spaces of the hand after having passed through the canalis carpi (Figs 374, 375, 376) In the canal, they lie close together in two layers The tendons of the deep flexors lie one by one in normal sequence, the tendons of the superficial flexors, however, superimpose two by two. The radial group of the superficial tendons is covered by the nervus medianus

All these structures are confined to the canal by two covering membranes, the ligamentum carpi volare and the ligamentum carpi transversum (also called the "anterior annular ligament") The ligamentum carpi volare is a continuation of the fascia antibrachii, above the wrist, it forms a transverse fascia, which passes over into the ligamentum carpi transversum Besides the flexor tendons, it covers the ulnar artery and nerve as both emerge to cross over the ligamentum carpi transversum The latter is a tough fibrous band, which crosses the arch formed by the carpal bones and connects the os naviculare and os multangulum majus on the radial side with the os pisiforme and os hamatum on the ulnar side The ulnar nerve and artery cross the ligament on the radial side of the os pisiforme to dip beneath the palmar fascia On the radial side, the ligament is crossed by the superficial volar branch of the radial artery, which helps to form the arcus volaris superficialis.

Bursae (Figs 374, 376) The tendons of the musculi flexorum digitorum communium are invested in the carpal canal by a common synovial sheath (ulnar bursa) The latter commences just proximal to the ligamentum carpi transversum, and stops in the middle of the palm, with the exception of the fifth finger. Here, in the majority of cases, the

XXIX

THE MUSCLES, TENDONS, NERVES, AND BLOOD VESSELS

It is customary to discuss the surgery of the muscles and tendons separately from that of the nerves and blood vessels This distinction however is abandoned to simplify the discussion since the anatomical and functional relationships of these structures are particularly close in the hand

Anatomy

DEEP PALMAR STRUCTURES

The bulk of the deep palmar structures lie beneath the palmar aponeurosis within the three main spaces thenar space middle palmar space and hypothenar spaces (Figs 373 374 375)

Thenar Space (Figs 374 375) This contains the short muscles of the thumb the musculus abductor pollicis brevis flexor pollicis brevis, adductor pollicis, opponens pollicis and the tendon of the flexor pollicis longus. The superficial ramus of the arteria radialis which branches off to form the arcus volaris superficialis lies upon these muscles while the deep ramus for the formation of the arcus volaris profundus enters the bottom of the thenar space between the first and second metacarpal bones The innervation of the musculus abductor pollicis brevis opponens pollicis and part of the short flexor is provided by the nervus medianus while the other part of the short flexor and the adductor is *supplied by* the nervus ulnaris

Middle Palmar Space (Figs. 374 375 376) The superficial part of the space directly beneath the palmar aponeurosis comprises the arcus volaris superficialis (arteria ulnaris and small branch of arteria radialis)

DORSAL STRUCTURES

Fascia Dorsalis (Fig 378) The extensor tendons are covered by a veil of tough connective tissue, the deep dorsal fascia, upon which the subcutaneous veins and the cutaneous branches of the nervus radialis and the nervus ulnaris are resting The dorsal fascia is connected proximally with the deep fascia of the forearm and distally with the dorsal aponeurosis of the fingers

Ligamentum Carpi Dorsale (Figs 378, 379) At the level of the wrist, the fascia becomes thick and tough, forming the ligamentum carpi dorsale (posterior annular ligament). Laterally, the ligament is attached to the facies radialis and processus styloideus radii, medially to the processus styloideus ulnae and the ulnar border of the carpus Septal partitions connect the ligament with the dorsal surface of radius and ulna, forming six tunnels for the passage of the extensor tendons and their sheaths

Tendons and Muscles of Middle Portion of Hand (Figs 379, 380)· After the extensor tendons have passed the osteofascial spaces beneath the ligamentum carpi dorsale, they divide into an ulnar and a radial group The ulnar group fans out over the middle part of the hand to the second to fifth fingers, while the radial group passes to the radial side of the midhand and the thumb, forming the tabatière anatomique, which contains the arteria radialis and the ramus superficialis nervus radialis. There are altogether six extensor tendons for the second, third, fourth, and fifth fingers, one tendon for the third and fourth fingers, and two each for the second and fifth fingers Near the metacarpophalangeal joints, the tendons are connected with each other by fibrous bands, the juncturae tendinum.

Beneath the extensor tendons are found the four musculi interossei dorsales, which arise from the metacarpal bones and which are inserted in a way similar to that of the volar group (see Fig 381) While the volar group adduct the second, fourth, and fifth fingers toward the third finger, the dorsal group abducts them The musculi interossei dorsales also aid the action of the musculi lumbricales in flexing the fingers in the metacarpophalangeal joints and extending the fingers in the interphalangeal joints Together, the interossei and lumbricales form the intrinsic system of the hand (see p 711) The interossei dorsales are innervated by the deep palmar branch of the ulnar nerve

Digital Insertion of Tendons (Fig 381) After having crossed the metacarpophalangeal joint, each extensor tendon flattens out to form an aponeurosis over the proximal phalanx, which is intimately connected with the capsule and lateral ligaments of the metacarpophalangeal joint The extensor tendon also inserts into the dorsum of the proximal

synovial bursa becomes continuous with the tendon sheath of this finger The long flexor tendon of the thumb has a separate sheath (radial bursa) which commences just proximal to the ligamentum carpi transversum and reaches to the second phalanx. In about half of the cases, this bursa communicates with the ulnar bursa Distally the two flexor tendons of each finger are surrounded by a similar synovial sheath which starts at the level of the heads of the metacarpal bones and reaches to the third phalanx of each finger The tendons on their way through the digital sheath are bridged by strong fibrous ligaments ligamenta vaginalia which insert at the proximal and middle phalanx on each side These so-called pulleys confine the tendons in the bed Their action is supported by other less strong ligaments over the joints (ligamenta cruciata and ligamenta annularia) The long flexor tendon of the thumb has only one vaginal ligament opposite the proximal phalanx.

Insertion of Tendons (Fig 377) In the proximal part of each digital sheath the two flexor tendons are superimposed At the level of the proximal phalanx the superficial flexor tendon divides into two slips, through which the deep flexor tendon passes. These slips are inserted into the sides of the middle phalanx at its base while the deep flexor tendon is inserted into the base of the distal phalanx. The tendon of the musculus flexor pollicis longus passes alone through the osseoaponeurotic canal and is inserted into the base of the terminal phalanx. Before insertion to the phalanges each tendon connects itself with the bone by fine fibrous filaments, called vincula tendinum

Musculi Lumbricales (Figs 374 376) The musculi lumbricales are situated between the deep flexor tendons, from which they originate and form the base for the digital nerves and vessels. They pass toward the dorsal side of the finger and insert into the tendinous expansion of the musculus extensor digitorum communis (Fig 381) Their action is to flex the proximal phalanges and to extend the middle and distal phalanges of the second to fifth fingers together with the musculi interossei forming the intrinsic muscle system of the hand Its function is described on p 711

Musculi Interossei These form the deepest layer of muscles and are situated in the interspaces of the metacarpal bones They originate at their lateral surfaces and like the former muscles insert into the tendinous expansion of the musculus extensor digitorum communis Their function is to support the action of the lumbrical muscles with which they form the intrinsic system of the hand (see p 711) and to adduct the proximal phalanges of the second fourth and fifth fingers toward the middle finger They are all supplied by the ulnar nerve

with the tendons of the lumbrical and interosseus muscles and continue distally to the proximal end of the dorsum of the terminal phalanx for insertion Despite the insertions of the extensor digitorum communis into the middle and terminal phalanges, this muscle can extend these two phalanges only very slightly, if at all, when the proximal phalanges are in extension. This occurs because so much of each of the extensor digitorum communis tendons is inserted into the dorsum of the proximal phalanges that when the muscle contracts, most of its power is concentrated in extending the proximal phalanges.

"Furthermore, this firm anchoring of the tendons to the proximal phalanges permits but little extension of the middle and terminal phalanges by the extensor communis when the proximal phalanges are in the extended position. The arrows in Fig 381 show how the tendons of the lumbrical muscles and interosseous muscles, especially the volar interossei, inserted into the lateral slips of the extensor digitorum communis, are able to do most of the extending of the middle and terminal phalanges when the proximal phalanges are extended The situation changes, however, as soon as the extensor digitorum communis relaxes sufficiently to permit the flexors digitorum sublimis and profundus to begin flexing the middle and terminal phalanges Simultaneously, this causes the extensor communis 'hood' to be pulled distally away from the metacarpophalangeal joint just enough, so that when the lumbricals and interossei contract, they then flex the proximal phalanges. In fact, the important flexors of the proximal phalanges are the lumbrical and interosseous muscles

"It seems almost paradoxical to have these intrinsic muscles flex the proximal phalanges and extend the middle and terminal phalanges But a study of Fig 381 will show that if the dorsal expansion or 'hood' is pulled proximally to the metacarpophalangeal joint (this occurs when the extensor digitorum communis has extended the proximal phalanges), contraction of the lumbricales and interossei extends the middle and terminal phalanges On the other hand, when the 'hood' is pulled distal to the metacarpophalangeal joint (this occurs with the synergic relaxation of the extensor digitorum communis and flexion of the digitorum sublimis and profundus), contraction of the lumbricales and interossei results in flexion of the proximal phalanges Now when the fingers are flexed (for example, 45 degrees), the extensor digitorum communis, via its lateral slips, takes over about half the control of the extension of the middle and terminal phalanges, and when the fingers are three-fourths flexed, the extensor digitorum communis assumes full control in the extension of these phalanges

phalanx. By means of this insertion the tendon can carry out two functions first to extend the proximal phalanx to extension and hyperextension and second to stabilize the metacarpophalangeal joints so that the intrinsic muscles (lumbricales and interossei) not only can extend the middle and distal phalanges but are also able to give lateral movements to the fingers Over the first interphalangeal joint the dorsal aponeurosis splits into three slips the central slip fused with the joint capsule is inserted to the base of the middle phalanx the two lateral slips after having received the insertions of the musculi lumbricales and musculi interossei converge to fuse with the capsule of the terminal joint and to attach to the base of the terminal phalanx

Intrinsic Muscles of Fingers The lumbricales and the interossei make up the intrinsic muscle system of the hand—the most important structure for the stabilization of the hand and fingers Textbooks commonly give an accurate description of the anatomy but fail to consider the synergic balancing function Among other investigators Sterling Bunnell and his co-workers Howard and Pratt have advanced our knowledge of the function of the intrinsic system which has been recently described in a stimulating review by Eyler Markee and E. W Lampe.

The intrinsic muscles act in coordination Together with the long extensor tendon they exert a synergic balancing function which permits a variety of finger motions The difference in action is made possible by a remarkable mechanism at the base of the finger in the form of a thin sliding aponeurotic sleeve ("hood") which with transverse fibers connects the conjoined lumbrical interosseus tendons with the extensor tendon over the dorsum of the proximal phalanx. This aponeurotic sling can be shifted forward and backward with the extensor tendon acting like a gear shift. By means of this mechanism the intrinsic muscles can stabilize the metacarpophalangeal joints in flexion so that the long extensor can extend the interphalangeal joints. By means of this same device the long extensor tendons can stabilize the metacarpophalangeal joints in extension so that the intrinsic muscles can give lateral motion and can extend the interphalangeal joints. This synergic action improves the ability of the long extensors to extend the interphalangeal joints when the metacarpophalangeal joints are flexed as well as that of the intrinsic muscles to extend the interphalangeal joints when the metacarpophalangeal joints are extended

The following description of the synergic-stabilizing action of the intrinsic system in collaboration with the extensor tendon is taken from E W Lampe (Fig 381) A central slip inserts into the dorsum of the proximal end of the middle phalanx. Two lateral tendinous slips unite

forearm. Therefore, only testing the intrinsic muscles of the hand and the sensation is of value Loss of sensation of the fifth finger and the ulnar half of the fourth finger, loss of abduction and adduction of the completely extended fingers, and loss of adduction of the thumb—that is, an inability to make a perfect O between thumb and index finger or to hold a piece of paper firmly between these fingers—indicate injury to the ulnar nerve Loss of sensation of the palmar surface of the thumb, index, and middle fingers and of the radial half of the fourth finger,

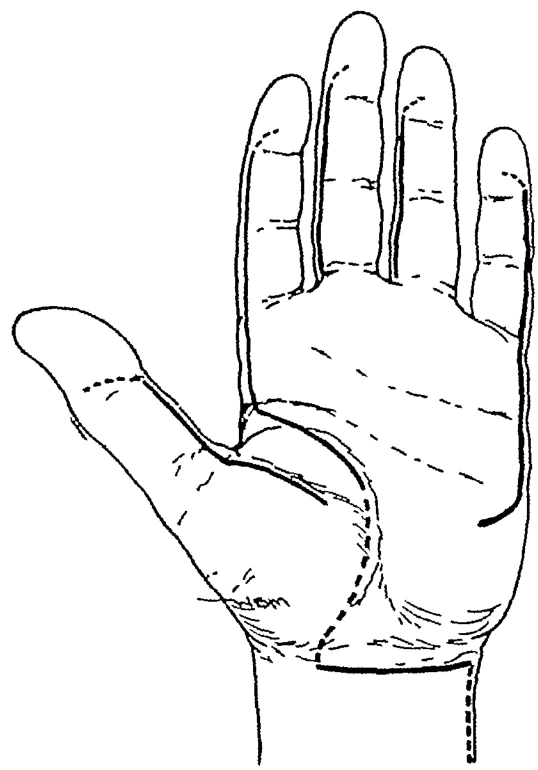


Fig 382 Correct incisions in hand At fingers, lateral incisions are best In palm, incisions should be parallel with creases, in wrist, they should be transverse Dotted lines indicate additional extensions and combinations (H May Surg, Gynec & Obst)

together with the inability to rotate the thumb to face the fingers (opposition), indicates injury to the median nerve Loss of sensation of the radial half of the dorsum of the hand is the sign of injury to the superficial branch of the radial nerve

In older cases in which the injury has resulted in disability of flexion of the fingers, the degree of impairment of flexion should always be re corded Boyes offers a simple way of measuring. He states· "In order t flex the interphalangeal joints of the finger completely, the deep flexo tendon must make an excursion of three-fourths of an inch in the prox mal segment of the finger and one and three-eighths inches in the pal If this excursion is limited, the tip of the finger fails to touch the dist

The interosseous muscles gain partial insertion not only into the lateral aspects of the proximal ends of the proximal phalanges but also into the lateral aspects of the capsules of the metacarpophalangeal joints. It is these insertions which enable the ulnar nerve-controlled interossei to spread and approximate the fingers.

Physiology of Tendons

The function of the tendon is to transmit the contractile force of the muscle. Hence, its gliding mechanism is of the utmost importance The tendon is surrounded on all sides by a loose fatty meshwork of tissue, which is rich in elastic fibers enabling the tendon to glide to and fro This tissue is termed paratenon The tendon sheath is a closed sac, containing fluid It is found wherever the tendon changes its direction and serves as a fluid buffer to diminish friction at that point. The sheath consists of a parietal and a visceral layer Both layers are connected with each other by the mesotenon, which carries the nutrient vessels and nerves. Other main blood vessels supplying the tendon proper run through the lowermost fibers of the corresponding muscle and paratenon The physiology of the tendons has been well described by Bielsaski and Mayer, and by L. Mayer

Division of Tendons and Nerves

OPEN INJURIES

General Rules and Technic

Diagnosis Whenever a wound occurs in the hand an exact anatomical test should be made for possible injuries of tendons and nerves Inability to flex the terminal phalanx indicates a division of the profundus tendon Partial disability to flex the proximal interphalangeal joint indicates a division of the sublimus tendon Inability to flex the terminal and proximal interphalangeal joints indicates a division of both flexor tendons. Inability to flex the terminal joint of the thumb indicates a division of the musculus flexor pollicis longus. On the dorsal side, the diagnosis may be less easy, owing to the support the extensor tendons receive from the lumbrical and interosseous muscles (*Fig* 381) *Furthermore the* fibrous bands, the juncturae tendinum (Fig 379) connecting the extensor tendons with each other may be strong enough to transmit the function of an uninjured tendon to its injured neighbor

With each tendon injury there is a possibility of nerve injury Hence preoperative tests should be made But it must be remembered that the muscle bellies of the long flexors and extensors are innervated in the

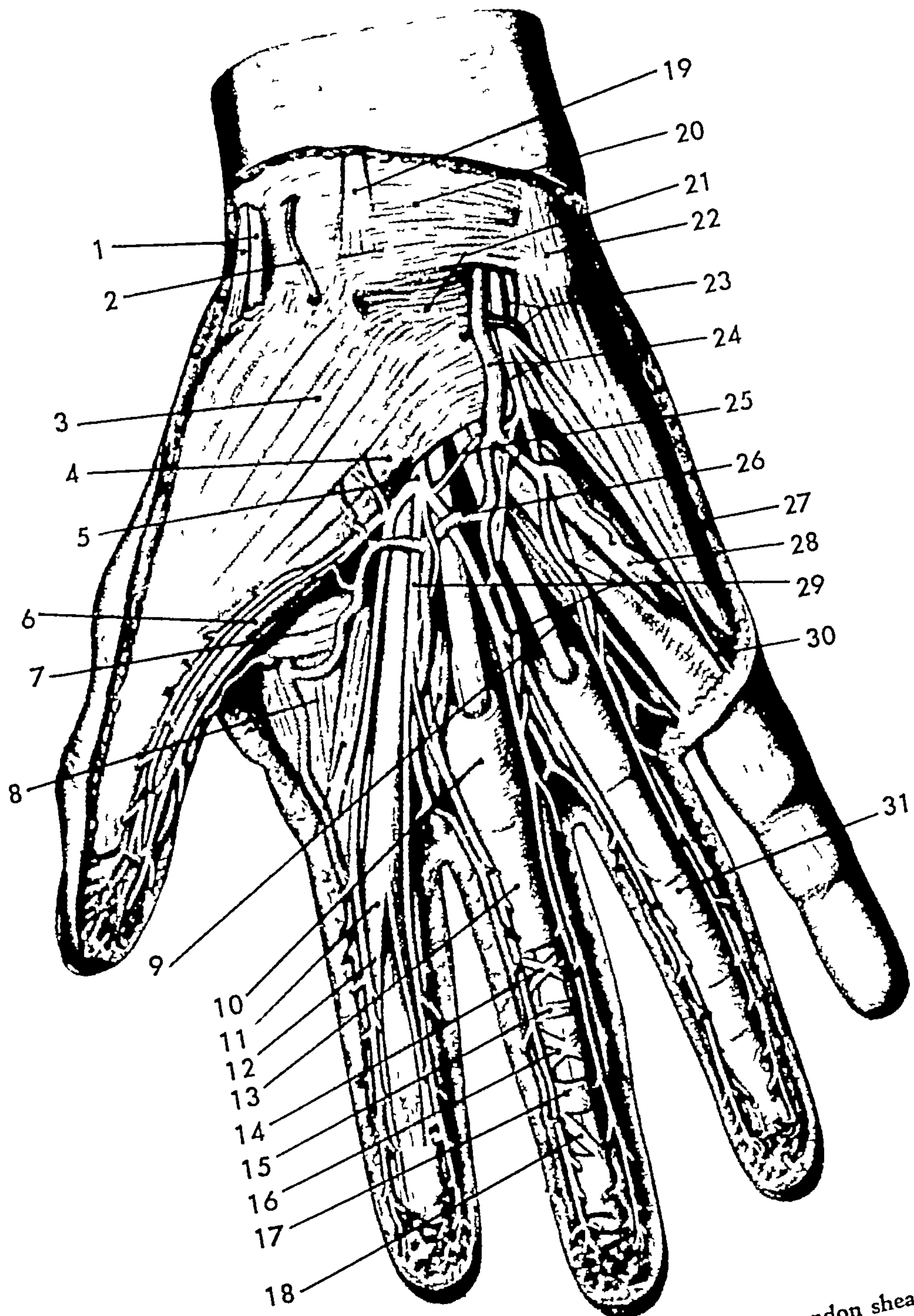


Fig 374 Superficial arcus volaris Palmar fasciae removed, tendon sheath of index finger removed, ligamenta vaginalia, annularia, and cruciata of middle finger depicted (R von Lanz and W Wachsmuth Praktische Anatomie Julius Springer, Berlin)

1 Tendon of the musculus abductor pollicis longus and musculus extensor pollicis brevis *2* Ramus volaris superficialis arteria radialis *3* Musculus abductor pollicis brevis *4* Musculus flexor pollicis brevis, caput superficiale *5* Nervus medianus *6* Tendon sheath of musculus flexor pollicis longus *7* Musculus adductor pollicis *8* Musculus interosseus dorsalis I *9* Musculi lumbricales I-IV.

10 Ligamentum vaginale accessorium *11* Musculus flexor digitorum sublimis (perforatus) *12* Musculus flexor digitorum profundus (perforans). *13* Ligamentum vaginale I *14* Ligamentum cruciatum *15* Ligamentum annulare *16* Ligamentum cruciatum *17* Ligamentum vaginale II *18* Ligamentum obliquum. *19* Tendon of musculus palmaris longus (severed)

20 Ligamentum carpi volare *21* Ligamentum carpi transversum *22* Os pisiforme *23* Ramus profundus nervus ulnaris and arteria ulnaris *24* Ramus superficialis nervus ulnaris and arteria ulnaris *25*· Rami anastomotici nervus ulnaris with nervrus medianus *26* Arcus volaris superficialis *27* Musculus abductor digiti quinti *28* Musculus flexor digiti quinti brevis *29* Arteriae and nervi digitalis volares communes *30* Arteria and nervus digitalis volaris proprius. *31* Tendon sheath of ring finger (intact)

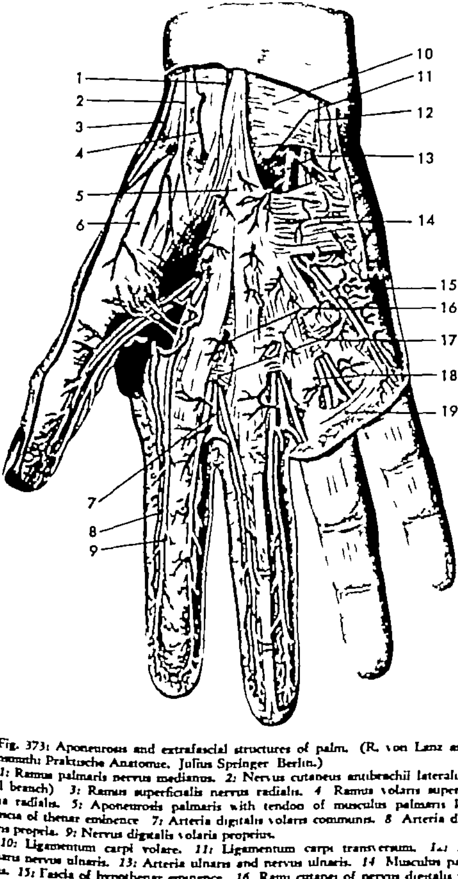


Fig. 373: Aponeurosis and extrafascial structures of palm. (R. von Lanz and W. Wachsmuth: Praktische Anatomie. Julius Springer. Berlin.)

1: Ramus palmaris nervus medianus. *2:* Nervus cutaneus antibrachii lateralis (terminal branch). *3:* Ramus superficialis nervus radialis. *4:* Ramus volaris superficialis arteria radialis. *5:* Aponeurosis palmaris with tendon of musculus palmaris longus. *6:* Fascia of thenar eminence. *7:* Arteria digitalis volaris communis. *8:* Arteria digitalis volaris propria. *9:* Nervus digitalis volaris proprius.

10: Ligamentum carpi volare. *11:* Ligamentum carpi transversum. *12:* Ramus palmaris nervus ulnaris. *13:* Arteria ulnaris and nervus ulnaris. *14:* Musculus palmaris brevis. *15:* Fascia of hypothenar eminence. *16:* Rami cutanei of nervus digitalis volaris communis. *17:* Fasciculi transversi. *18:* Retinacula. *19:* Ligamenta basium.

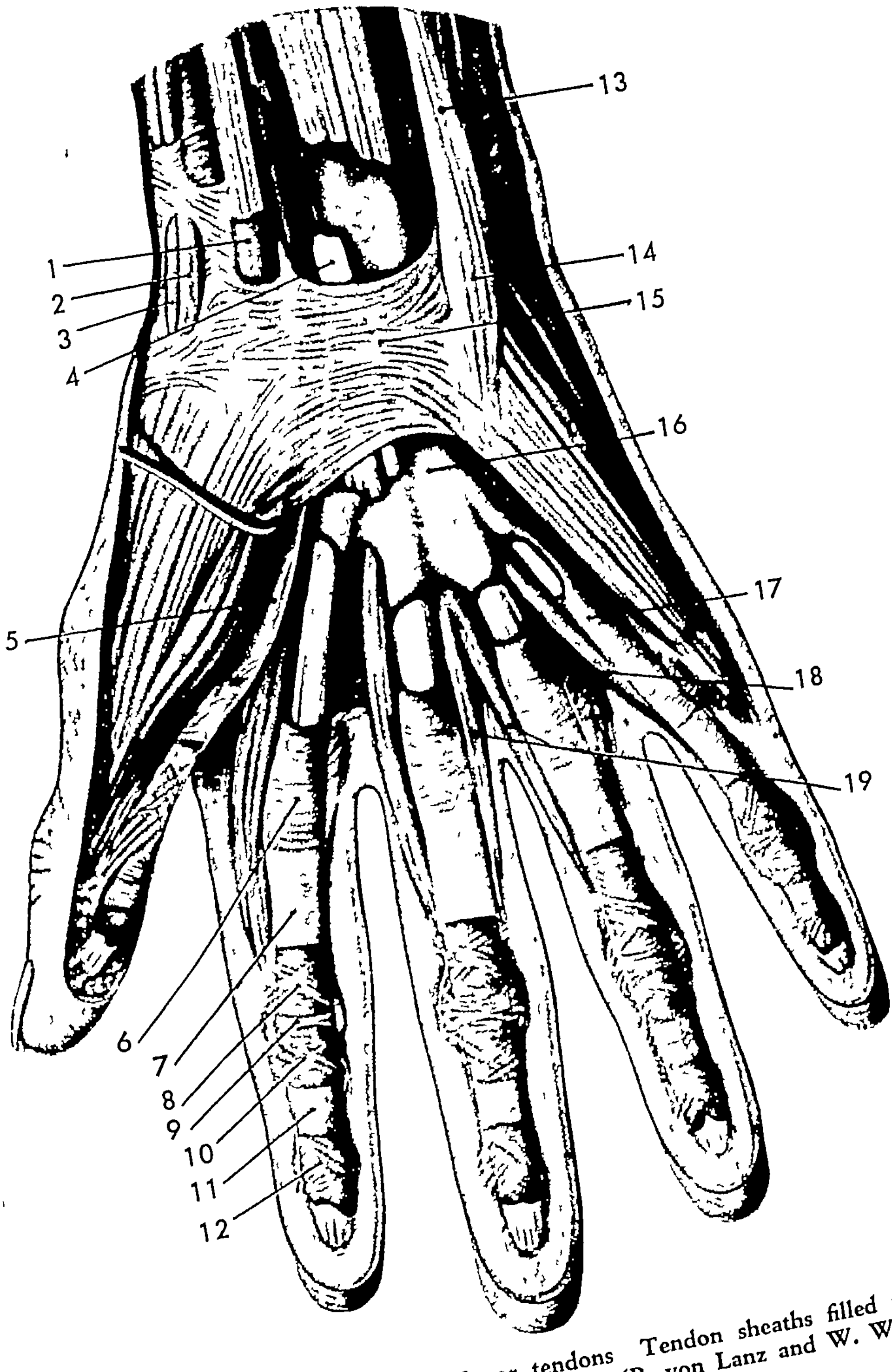


Fig 376 Gliding-apparatus of flexor tendons Tendon sheaths filled with blue rubbery mass Ligamentum carpi volare removed (R von Lanz and W. Wachsmuth Praktische Anatomie Julius Springer, Berlin)

1 Musculus flexor carpi radialis *2* Musculus abductor pollicis longus *3* Musculus extensor pollicis brevis *4* Nervus medianus *5* Tendon sheath of musculus flexor pollicis longus *6* Ligamentum vaginale accessorium. *7* Ligamentum vaginale I *8* Ligamentum cruciatum *9* Ligamentum annulare

10 Ligamentum cruciatum *11* Ligamentum vaginale II *12* Ligamentum cruciatum *13* Musculus flexor carpi ulnaris *14* Os pisiforme *15* Ligamentum carpi transversum *16* Common tendon sheath of musculus flexor digitorum *17* Tendon sheath of flexor tendons of little finger continuous with common tendon sheath in wrist *18* Musculus lumbricalis IV. *19* Musculus lumbricalis III (insertion also at middle finger, exceptional case)

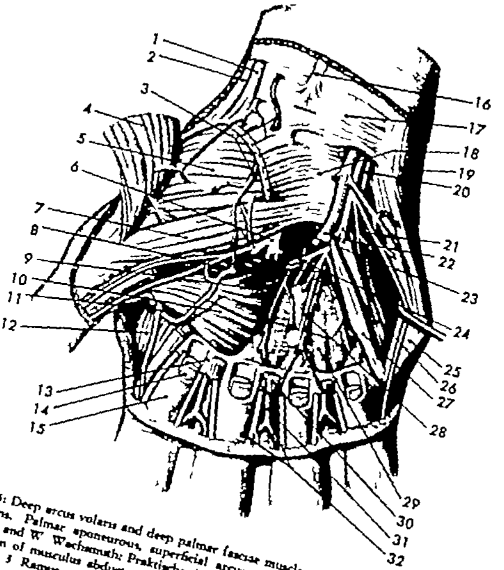


Fig. 3 75: Deep arcus volaris and deep palmar fasciae muscles and thenar and hypothenar regions. Palmar aponeurosis, superficial arcus volaris, and tendons removed. (R. von Lanz and W. Wachsmuth: Praktische Anatomie. Julius Springer Berlin.)

1 Tendon of musculus abductor pollicis longus. 2. Tendon of musculus extensor pollicis brevis. 3 Ramus volaris superficialis arteria radialis. 4: Musculus abductor pollicis brevis (severed) 5 Musculus opponens pollicis. 6 Nervus medianus with branches to muscles of thumb 7 Musculus flexor pollicis brevis, caput superficiale. 8 Musculus flexor brevis, caput profundum. 9 Musculus adductor pollicis, caput obliquum.

10 Musculus adductor pollicis, caput transversum. 11 Anastomosis of arcus volaris superficialis to arteria metacarpea volaris I. 12. Musculus interosseus dorsalis I 13: Ligamenta capitulorum transversa. 14: Tendons of musculus flexor digitorum (severed) 15: Ligamentum vaginale I 16: Tendon of musculus palmaris longus (severed) 17: Ligamentum carpi volare 18 Ligamentum carpi transversum. 19: Os pisiforme

20 Ramus profundus nervus ulnaris. 21: Ramus profundus arteria ulnaris. 22: Ramus superficialis nervus ulnaris and arteria ulnaris (severed) 23 Tendons of musculus flexor digitorum in carpal canal (severed) 24: Arcus volaris profundus and ramus profundus nervus ulnaris with muscle branches. 25: Musculus abductor digiti quinti. 26 Musculus opponens digiti quinti. 27 Musculus flexor digiti quinti brevis. 28: Arteriae metacarpea volares and articular branches of ramus profundus nervus ulnaris. 29 Fascia palmaris profunda.

30 Musculi lumbricales III (severed) 31 Arteria digitalis communis (severed) 32: Nervi and arteria digitales volares proprii.

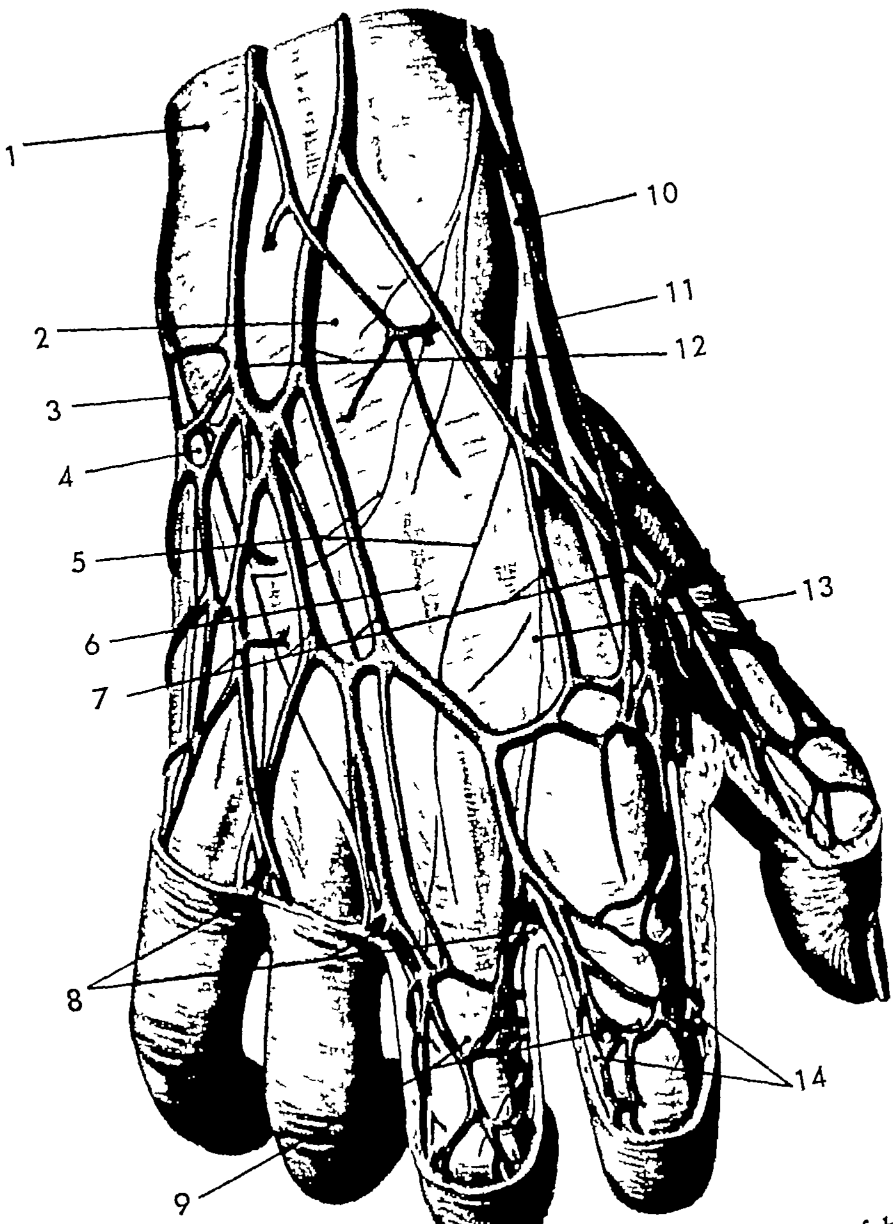


Fig 378 Veins, skin, nerves, and superficial fasciae of dorsum of hand. (R von Lanz and W Wachsmuth Praktische Anatomie. Julius Springer, Berlin) *1* Fascia antibrachii *2* Ligamentum carpi dorsale *3* Vena salvatella *4* Ramus dorsalis nervus ulnaris *5* Rami anastomotici *6* Fascia dorsalis superficialis *7* Venae metacarpeae dorsales *8* Venae intercapitulares *9* Arcus venosi digitalis *10* Ramus superficialis nervus radialis *11* Vena cephalica pollicis *12* Venae cephalicae accessoriae *13* Nervus digitalis communis dorsalis *14* Nervi digitales dorsales proprii.

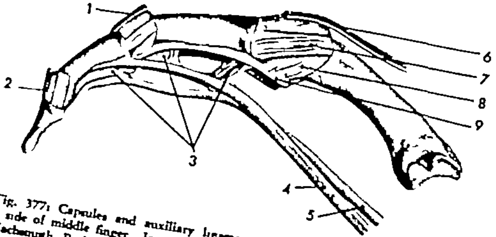


Fig. 377: Capsules and auxiliary ligaments of finger joints. Vincula tendinea. Ulnar side of middle finger. Joints filled with blue rubbery mass. (R. von Lanz and W. Wachsmuth. Praktische Anatomie. Julius Springer Berlin.)

Articulatio Interphalangea Proximalis. 1: Middle slip of aponeurosis dorsalis.

Articulatio Interphalangea Distalis. 2: Lateral slip of aponeurosis dorsalis. 3: Vincula tendinea. 4: Tendon of musculus flexor digitorum sublimis. 5: Tendon of musculus flexor digitorum profundus.

Articulatio Metacarpophalangea. 6: Aponeurosis dorsalis. 7: Ligamentum collaterale. 8: Ligamentum collaterale accessorium. 9: Fibrocartilago volaris.

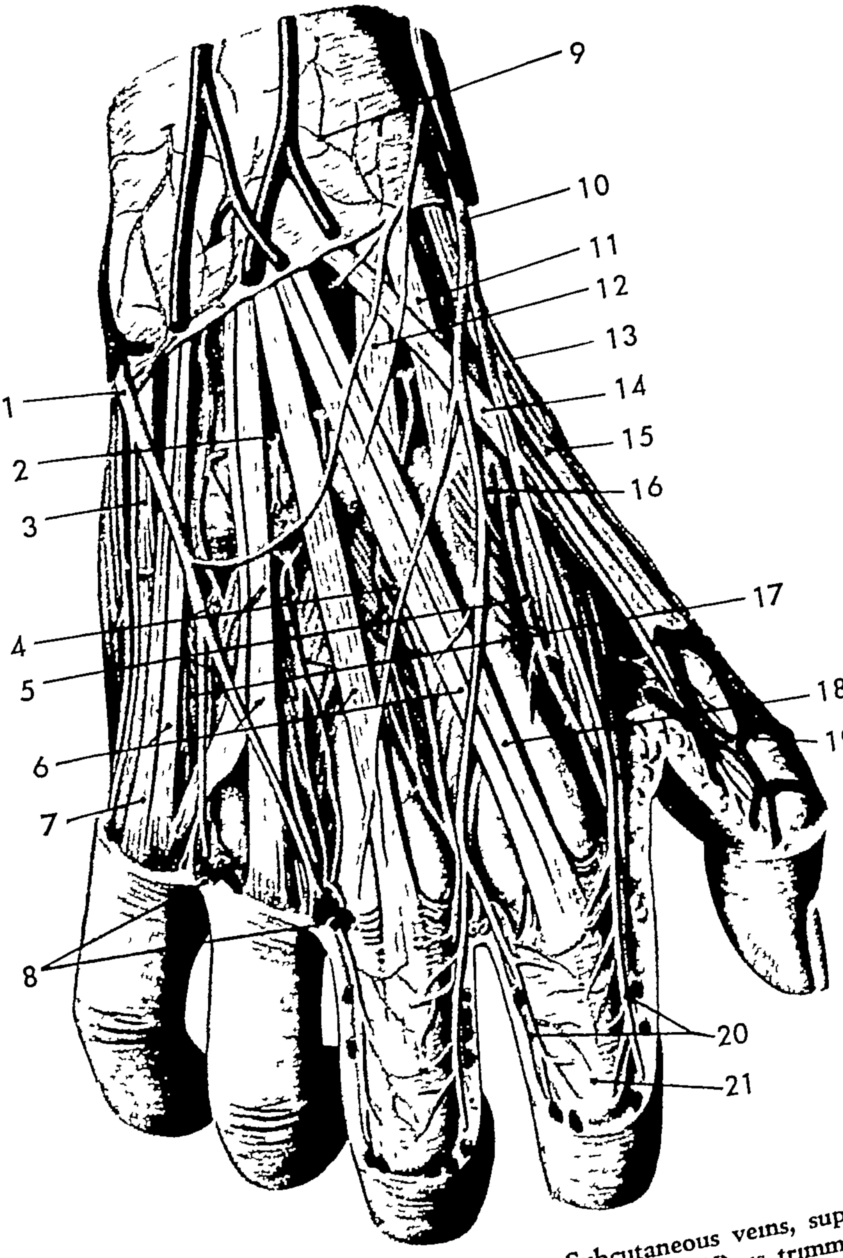


Fig 380 Deep layer of dorsum of hand. Subcutaneous veins, superficial fasciae, and juncturae tendinea are removed Distal junctura (IV/V) is trimmed distally and displaced proximally and radially to expose spatium interosseum IV (R. von Lanz and W. Wachsmuth Praktische Anatomie Julius Springer, Berlin)

1 Ramus dorsalis nervus ulnaris *2* Ramus carpeus dorsalis *3* Tendon of musculus extensor carpi ulnaris *4* Rami perforantes *5* Arteriae metacarpeae dorsales *6* Tendons of musculus extensor digitorum communis *7* Tendon of musculus extensor digiti quinti proprius *8* Venae intercapitulares *9* Rete arteriosum carpeum dorsale *10* Ramus superficialis nervus radialis *11* Musculus extensor carpi radialis longus *12* Musculus extensor carpi radialis brevis *13* Musculus abductor pollicis longus *14* Musculus extensor pollicis longus *15* Musculus extensor pollicis brevis *16* Arteria radialis *17* Musculi interossei dorsales *18* Tendon of musculus extensor indicis proprius *19* Rete venosum dorsale pollicis. *20* Arteriae and nervi digitales dorsales proprii. *21.* Aponeurosis dorsalis.

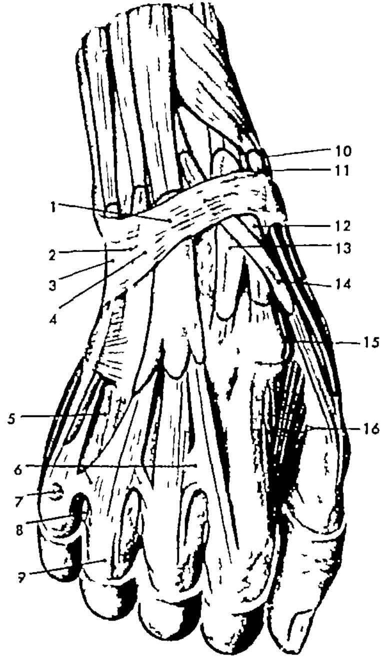


Fig. 379: Extensor tendons tendon sheaths, and bursae of dorsum of hand. Tendon sheaths and bursae filled with blue rubbery mass. (R. von Lanz and W. Wachsmuth. Praktische Anatomie Julius Springer Berlin.)

Ulnar Group of Tendon Sheaths. *Fourth Space* *1:* Musculus extensor digitorum communis, musculus extensor indicis proprius.

Fifth Space *2:* Musculus extensor digiti quinti proprius.

Sixth Space *3:* Musculus extensor carpi ulnaris. *4:* Ligamentum carpi dorsale *5:* Fascia dorsalis profunda. *6* Juncturae tendinea *7:* Bursa mucosa subcutanea metacarpophalangea dorsalis. *8* Bursa mucosa intermetacarpophalangea. *9* Aponeurosis dorsalis.

Radial Group of Tendon Sheaths. *First space* *10:* Musculus abductor pollicis longus. *11:* Musculus extensor pollicis brevis.

Second Space *12.* Musculus extensor carpi radialis longus. *13* Musculus extensor carpi radialis brevis.

Third Space *14:* Musculus extensor pollicis longus. *15:* Arteria radialis. *16.* Musculus interosseus dorsalis I

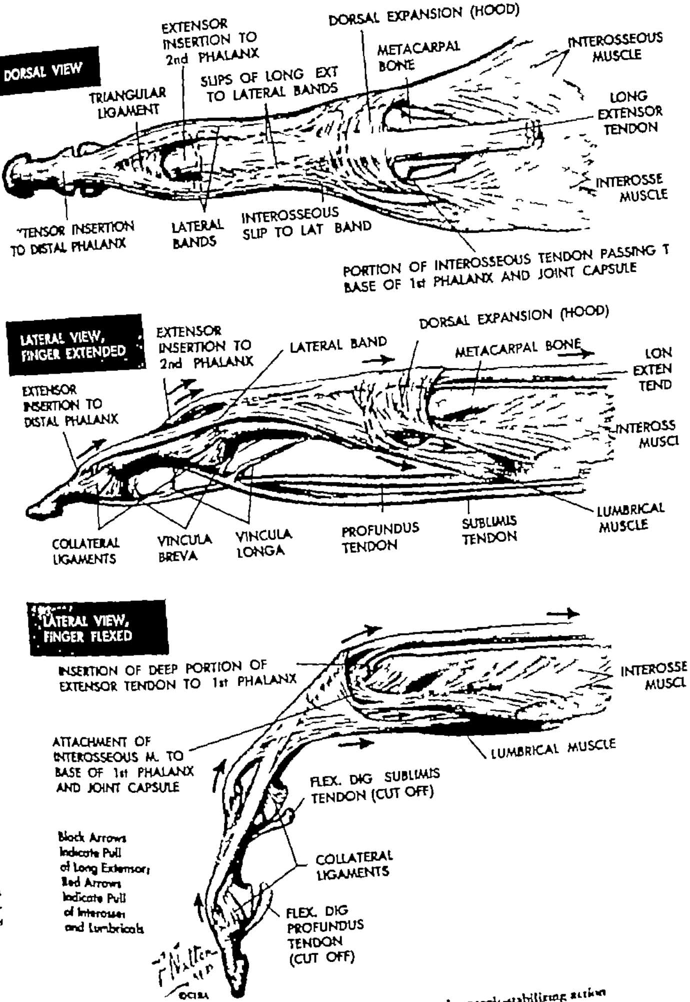


Fig. 381: Anatomy and display of function and synergic-stabilising action
... al Symposia)

following the accident But if the wound is soiled or contused or the patient is seen after the eight-hour limit, the wound is excised and closed, but the repair of tendons and nerves is delayed until the wound has healed, usually after from three to four weeks Infected wounds, however, are left open, and tendons and nerves should not be repaired until at least six months have elapsed since the healing of the wound Since the introduction of penicillin, the time interval can be shortened to three months if penicillin is administered pre- and postoperatively

General Technic: The author follows the general and now classical rules of Bunnell, Koch and Mason The operative field is cleansed asepti-

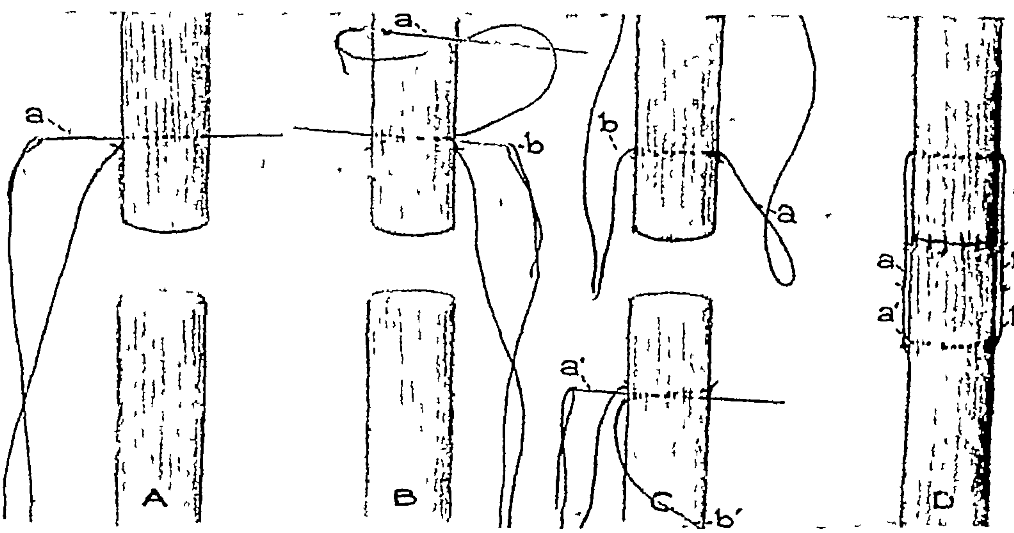


Fig 384 Tendon suture (Mason) Small bundle of peripheral tendon fibers is caught with a suture about 1 cm (3/8 inch) above tendon end Short end of suture is cut Long end of suture is passed through tendon with needle to come out on opposite side at level of about 0 5 cm (3/16 inch) higher than level of knot. Second suture is tied about small bundle of peripheral tendon fibers just below point of emergence of first suture Short end of suture is cut, long end of suture is passed with needle through tendon so as to come out on opposite side directly above knot of first suture Similar sutures are placed in opposite stump and tendons approximated by tying corresponding sutures A few coaptation sutures are placed to coapt tendon stumps end-to-end

cally (p 4) The operation is performed under general anesthesia A blood-pressure cuff is applied and inflated to obtain a bloodless field Before inflation, the arm is elevated and held elevated for five minutes The cuff is then pumped to a pressure of 280 mm of mercury This pressure may be maintained as long as necessary to complete the dissection It is then lowered to enable the surgeon to ligate the bleeders When all bleeders have been ligated, the arm is again elevated for five minutes and the cuff is reinflated to 280 mm of mercury and kept inflated until the operation is completed and the pressure dressing is applied In primary repairs, the wound edges should be excised as sparingly as possible. If,

crease of the palm The measurement of this distance to the distal crease, thus becomes an easily recorded and readily understood index of the results of flexor tendon action in the fingers Function of the long flexor tendon of the thumb is measured by the degrees of flexion of the interphalangeal joint.

Primary versus Secondary Repair of Tendons and Nerves There is no question that the prognosis is better for the functional result after a primary than after a secondary tendon and nerve repair there is also no

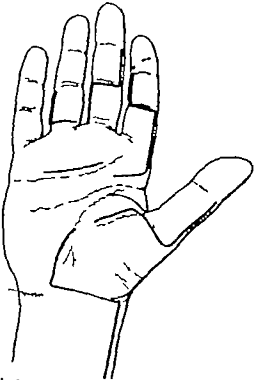
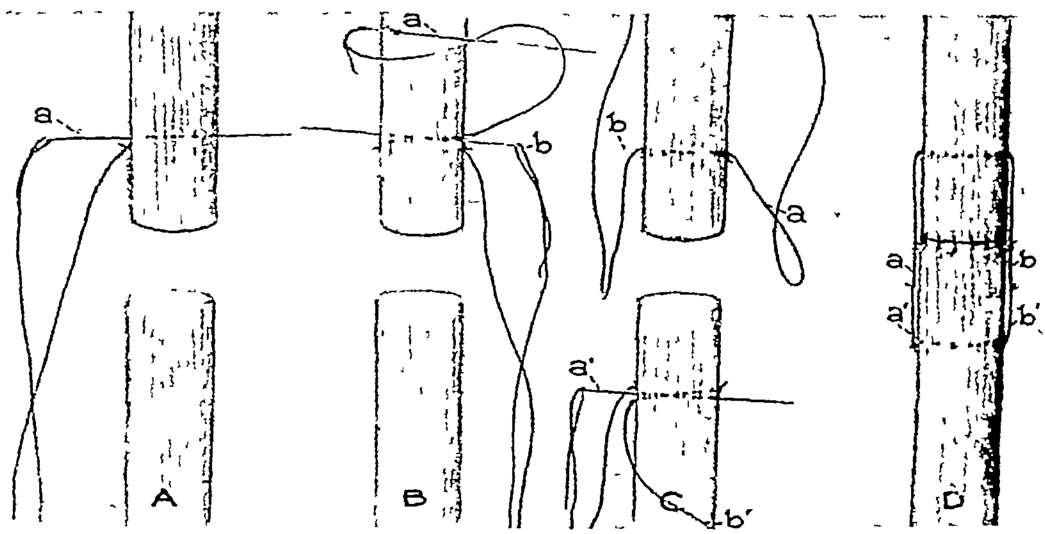


Fig. 383: Bayonet incisions in hand (Mason) (H May Surg., Gynec. & Obst.)

question that the prognosis is poor for secondary repairs following failure of a primary one Hence in any open tendon and nerve injury the surgeon is confronted with the question of whether to repair tendons and nerves primarily or simply to close the wound and to delay the tendon and nerve repair until after the wound has healed. Immediate repair of divided tendons and nerves (except for tendons severed within the flexor sheaths) can be undertaken (1) if the wound is clean and made by sharp instruments such as glass or knives (2) if the emergency dressing was carried out aseptically and (3) if the patient is seen within a few hours after the accident Some authors place the time limit from two to six hours, others up to twelve or even twenty four hours following the accident The writer prefers to suture tendons and nerves up to eight hours

following the accident But if the wound is soiled or contused or the patient is seen after the eight-hour limit, the wound is excised and closed, but the repair of tendons and nerves is delayed until the wound has healed, usually after from three to four weeks Infected wounds, however, are left open, and tendons and nerves should not be repaired until at least six months have elapsed since the healing of the wound Since the introduction of penicillin, the time interval can be shortened to three months if penicillin is administered pre- and postoperatively

General Technic: The author follows the general and now classical rules of Bunnell, Koch and Mason The operative field is cleansed asepti-



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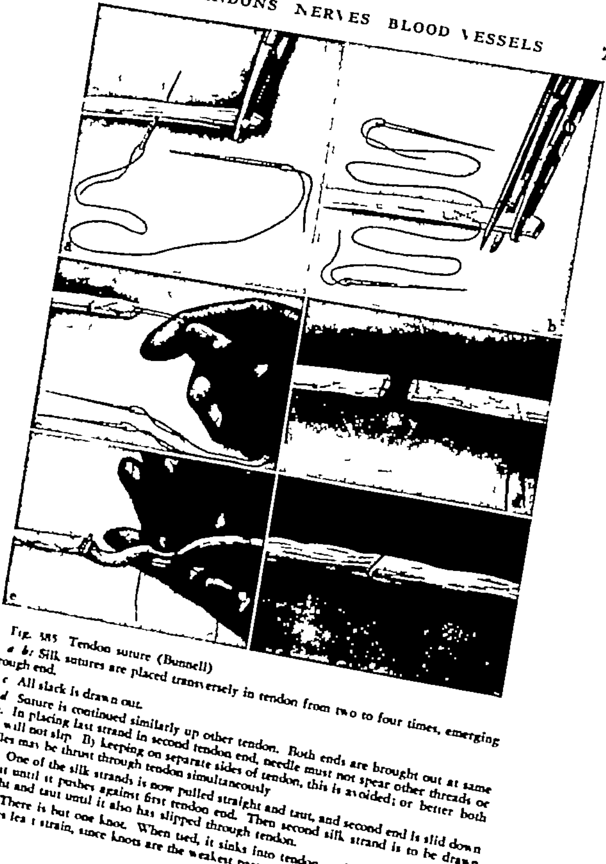


Fig. 585 Tendon suture (Bunnell)

a b: Silk sutures are placed transversely in tendon from two to four times, emerging through end.

c All slack is drawn out.

d Suture is continued similarly up other tendon. Both ends are brought out at same side. In placing last strand in second tendon end, needle must not spear other threads or they will not slip. By keeping on separate sides of tendon, this is avoided; or better both needles may be thrust through tendon simultaneously

e One of the silk strands is now pulled straight and taut, and second end is slid down over it until it pushes against first tendon end. Then second silk strand is to be drawn straight and taut until it also has slipped through tendon.

f There is but one knot. When tied, it sinks into tendon, and it is placed where it receives least strain, since knots are the weakest parts of a tendon suture

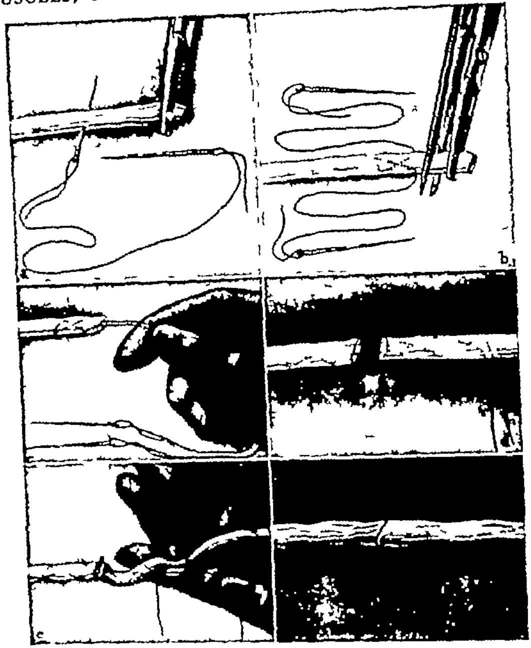


Fig 385 Tendon suture (Bunnell)

a b Silk sutures are placed transversely in tendon from two to four times emerging through end.

c All slack is drawn out.

d. Suture is continued similarly up other tendon. Both ends are brought out at same side In placing last strand in second tendon end, needle must not spear other threads or they will not slip. By keeping on separate sides of tendon, this is avoided or better both needles may be thrust through tendon simultaneously

e One of the silk strands is now pulled straight and taut, and second end is slid down over it until it pushes against first tendon end. Then second silk strand is to be drawn straight and taut until it also has slipped through tendon.

f There is but one knot. When tied, it sinks into tendon, and it is placed where it receives least strain, since knots are the weakest parts of a tendon suture.

slips of the sublimis tendon and the long flexor tendon passing between the slips If sublimis and profundus tendons are divided, it is generally agreed that only the profundus tendon should be united If the sublimis tendon is sutured also, a considerable mass of sutures is brought together in a small space, causing adhesions and preventing the profundus tendon from its action on the terminal phalanx

Step 1 EXPOSURE OF INJURED DIGITAL NERVES Lengthening of the wound is usually necessary (see Figs 382, 383) The nerve stumps are located and held away

Step 2. The digital tendon stumps are now located. They may reappear if the finger is flexed The proximal stump of the profundus tendon, however, has usually retracted, and is located from an additional incision within the palm or at the wrist (flexor pollicis longus). It is secured and guided through the original wound, as described previously

Step 3 If the laceration is at the level of the proximal phalanx, the stumps of the sublimis tendon are excised distally, the proximal stump has usually retracted The stumps of the profundus tendon are now sutured together To follow Mason's advice, the fibrous tendon sheath is excised over the area of repair for a distance of about 0 6 cm (1/4 inch) proximal and distal to the suture line. Thus, the line of suture comes to lie directly against fatty subcutaneous tissue with less likelihood of adhesions Then follows suture of the divided nerve If the laceration has occurred at the level of the middle phalanx beyond the insertion of the slips of the sublimis tendon, the profundus tendon is repaired in a similar way The tendon suture, however, may become difficult if the distal stump is short Here again, the part of the tendon sheath overlying the area of repair should be excised The wound is closed with interrupted sutures

Let it be stated again, however, that primary repair of both tendons severed within the flexor sheath should be very rarely considered and only under the most favorable circumstances In the vast majority of cases, it is much safer to close the wound with a few sutures and wait until it has healed—this usually takes from three to four weeks—and then perform a secondary repair consisting of tendon-grafting as described in detail on p 729 (primary tendon-grafting is still in the experimental stage) In a division of the pollicis longus, which is the only tendon in its sheath, this rule may be relaxed to a certain degree Should the division of other flexor tendons, however, occur within the extreme proximal or extreme distal part of the sheath, then it may be possible to place the tendon sutures outside the sheath through tendon advancement—as advised by Cutler and Mueller, and referred to by Littler, Nichols—and primary repair

musculus flexor pollicis longus has usually retracted so far that a separate transverse incision over the wrist is necessary to find it But before one locates the tendon the median nerve should be exposed and safeguarded After this precaution the tendon segment is pulled out of the proximal wound and the very tip grasped with a mosquito forceps A temporary guide suture is passed through the tip and tied The ends of the suture are left long To pull the proximal stumps peripherally into the original wound the opening of the proximal tendon canal in the original wound is located. A probe with eye first is inserted through the opening and passed in a retrograde manner through the canal until it appears in the proximal wound. The author has found the retrograde way more helpful than passing the probe from proximal to distal The temporary silk sutures are threaded into the eye of the probe and the probe is withdrawn pulling the proximal tendon stump into the original wound (compare with Fig 389)

Step 3 Then follows suture of the nerves This is a more difficult task than at the wrist particularly if the separation happens to be at a place where the palmar trunk divides into small branches Bunnell advises gathering the branches by a circular suture and suturing them en masse to the main trunk The tendons are united in the usual way If sublimis and profundus tendons are divided Koch and Mason doubt the wisdom of having two lines of sutures at the same level in close approximation To prevent adherence to one another they advise laying the lumbrical muscle between the two tendons at the line of suture and holding it in place by one or two fine sutures Then follows closure of the wounds

Volar Side of Fingers In this region primary repair should be attempted only under the most favorable circumstances The slightest infection or irritation following repair will cause scar formation within the sheath and adherence of the tendon to the sheath so that not only the immediate result is spoiled but also secondary repair becomes more difficult and handicapped Iselin Koch and Mason Cutler and others go so far as to advise against primary suture even under the most favorable circumstances Bunnell went even farther by recommending secondary repair and substitution of the entire divided tendon by a graft to avoid a suture line within the sheath Mason and Koch however with an improved technic demonstrated good functional results in cases when the operation was performed within two hours after the injury These wounds had been infected by sharp cutting instruments and were dressed aseptically Although the tendon division may occur at any point along the volar surface of the finger the most common site is at the level of the web At this level there are three tendons within the sheath—the two

overlying sheath is excised, as has been described (p 722) To prevent adhesions of the tendons with surrounding tissue, if the latter is cicatricial, interposition of a fat graft may be necessary (for source of graft, see end of paragraph) A fat graft is also placed between the tendons if sublimis and profundus have been severed and repaired and the suture line happens to be on the same level, it may be possible to suture together two neighboring lumbrical muscles between the suture lines If direct union of the tendon segments is impossible because of rigid contraction of the muscles or because tendons have sloughed away or become cicatricial, necessitating excision, one must resort to tendon-grafting or tendon transfer to bridge the intervening gap Thus, if both tendons, the sublimis and profundus, are divided, the distal end of the sublimis is excised while the proximal end of it is used as a free graft To bridge the gap in the profundus tendon, the graft, after it is placed between the segments of the profundus tendon, should be under moderate amount of tension To follow Koch's advice, the hand should be flexed in the wrist to an angle of 120 to 110 degrees and the fingers semiflexed at the metacarpophalangeal joints to an angle of 120 degrees The width of the resulting gap of the profundus tendon is now measured and this distance marked off on the proximal segment of the flexor sublimis The latter tendon is severed at that point and excised The excised part is laid between the ends of the profundus tendon and fastened to them with the usual tendon suture If a sublimis tendon is not available for grafting, the tendon of the palmaris longus or a long extensor of a toe may be utilized In using any of these tendon grafts, one should not forget that a graft will become adherent, unless a proper gliding mechanism is provided Hence, whenever a tendon graft is removed, the dissection should be performed in such a way as to leave the paratenon, or gliding-tissue (see p 713), intact, this is elastic fat tissue surrounding any tendon in the straight part of its course If it cannot be preserved, it is replaced by a graft of elastic areolar fat tissue, which is found lying as a thin layer upon the fascia lata or beneath it in the interspace between fascia lata and muscle fascia The use of foreign material is inadvisable

Rarely should one resort to transfer of a tendon from an uninjured finger (Mayer). So, for instance, the sublimis tendon of an uninjured index finger can be divided at a proper level and used to replace the divided flexor profundus tendon of the third finger Although sacrificing a sublimis tendon does not cause a serious disability, it does hamper the flexion of the involved finger to a certain degree and hence constitutes the disadvantage of the method

After the tendons are repaired, the nerves are sutured together. When-

becomes feasible. For example the profundus tendon if severed within the distal 1 inch can be advanced and sutured to the distal phalanx (for technic, see p. 731) after removal of its distal stump The distal portion of the tendon sheath with the exception of the annular ligament, should be excised. Primary repair is also feasible when sublimis and profundus tendons are divided near the proximal portion of the sheath In such a case the sublimis tendon is sacrificed and the proximal profundus stump is shortened so that the tendon suture of the profundus stumps is advanced proximally and comes to lie outside the sheath In addition the proximal part of the sheath is removed A 1 inch shortening of the profundus tendon is usually compensated for later on by stretching of its muscle belly

Dorsum of Hand (Case 146 p 1048) Severance of extensor tendons most often occurs over the dorsum of the wrist less often over the metacarpus and over the knuckles of the digital joints. In tendon injuries over the wrist, the commonest injury is division of the extensor digitorum communis, together with the extensor indicis proprius all of them being invested in the same compartment of and beneath the ligamentum carpi dorsale In injuries over the radial side of the wrist the whole radial group consisting of the abductor pollicis longus and both extensors of thumb and wrist may be injured or only the lateral group (abductor pollicis longus and extensor pollicis brevis) or the median group singly Severance of the ulnar group of extensors (extensor digiti quinti proprius and extensor carpi ulnaris) without injury to other tendons is rare Characteristic of dorsal tendon injuries over the wrist is marked retraction of the proximal as well as of the distal ends In separations over the metacarpus retraction of the distal segment is less marked particularly if only a single group is divided The fibers of the junctura tendinum (Fig 379) not only prevent retraction but as already mentioned may also be strong enough to transmit the function of an uninjured tendon to its injured neighbor Over the knuckles injury of the extensor tendon (dorsal fascia) without severance of the joint capsule is rare

In repairing severed dorsal tendons, the same rules are applicable as for the volar tendons. The original wound frequently must be enlarged The next step is location of severed nerves if there is clinical evidence of their involvement The stumps of the severed tendons are located and the corresponding stumps sutured together with the usual tendon sutures. Over the knuckles the rent in the extensor fascia and the underlying joint capsule are united with simple interrupted sutures. The divided nerves are finally sutured and the wound closed in layers.

through the middle phalanx, the wire is fastened over a button on the dorsal skin of the middle phalanx (Oakey) In addition, the terminal joint is immobilized with an intramedullary pin, which is buried beneath the skin (Fig 387, Cases 149, 150, pp 1053, 1054) Thus, external immobilization is not needed With intramedullary-pin fixation, surgical fusion of the terminal joint in 30-degree flexion without tenodesis may

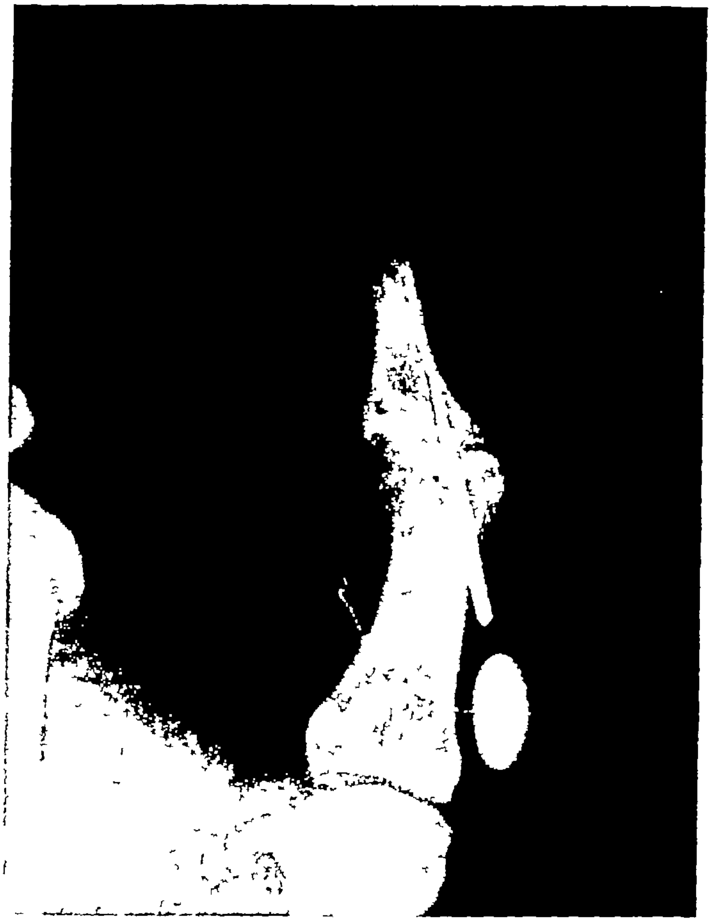


Fig 387 Division of flexor pollicis longus Tenodesis of distal stump to hold terminal phalanx in position of function With pull-out wire tendon is pulled into drill canal of first phalanx Immobilization of terminal joint with intramedullary pin

even be simpler Then, however, it becomes necessary to open the terminal joint from a dorsal horizontal incision and to remove the cartilaginous joint surfaces

In all other *cases, however, in which both tendons are severed or in* which after division of the profundus tendon the sublimis becomes adherent, tendon-grafting must be resorted to. If this is the case, the sublimis tendon is sacrificed and only the profundus tendon is lengthened with a graft Smaller-caliber tendon grafts are preferable Thinner grafts regenerate quicker, cause fewer adhesions, and are less constricted by the

ever the separation happens to be at a place where the palmar trunk divides into small branches, Bunnell advises gathering the branches by a circular suture and suturing them en masse to the main trunk. Closure of the wound follows

Volar Side of Fingers As mentioned previously (p 721), in the majority of these cases secondary repair should be the procedure of choice. The site of the injury is exposed with an adequate incision (Figs. 382 383) and if the digital nerves are divided their segments should be located first and then the tendon stumps The proximal segments of the divided tendons have usually retracted into the palm and should be exposed either by lengthening the former incision (the possibilities of proper lengthening are outlined in Figs 383 384) or from an additional incision in the palm (Fig 388) The long flexor tendon of the thumb gliding in a separate sheath usually has retracted even farther and must be located from a transverse incision above the wrist. To avoid injury to the median nerve at this point the latter should be exposed and retracted ulnarward before locating the tendon The next step is mobilization of the adherent tendon stumps The distal segments are approached from the empty part of the tendon sheath from which they have retracted. The empty sheath has usually collapsed and its walls have become adherent. It is opened by an incision close to its attachment to the bone. If possible, its floor (Koch) should be preserved while the roof usually must be excised except for a narrow proximal and distal pulley (annular ligament) to prevent bow-stringing If however the entire fibrous sheath must be excised one annular ligament (the proximal one) will need reconstruction as described later The distal tendon stump or stumps are now approached and carefully dissected free If the division has occurred over the proximal phalanx and involves sublimis and profundus tendons three tendon segments must be looked for the two slips of the sublimis tendon and the profundus tendon as it passes through the latter

In the vast majority of cases owing to contraction of the muscle belly or destruction of the tendons, the tendon stumps cannot be united with each other, and the gap between them must be bridged with a tendon graft (Figs. 388-390) There is however one exception If only the profundus tendon is severed and the intact sublimis tendon produces sufficient flexion of the proximal interphalangeal joint it is simpler to fuse the terminal joint by arthrodesis or tenodesis at approximately 30 degrees of flexion Tenodesis is possible if a distal profundus stump of sufficient length is left The distal stump is then armed with a pull-out wire suture as described on p 719 and pulled through a bone canal which is drilled

adherent to the distal end of the middle phalanx, either causing a flexion contracture of the terminal joint or preventing the graft from acting on the terminal phalanx) The next step consists in exposing the proximal tendon stumps, which usually have retracted into the palm or wrist (in the case of the flexor pollicis longus) They are located from a separate incision in the palm or over the wrist The tendons are freed from scar tissue, and pulled into the wound The range of motion should

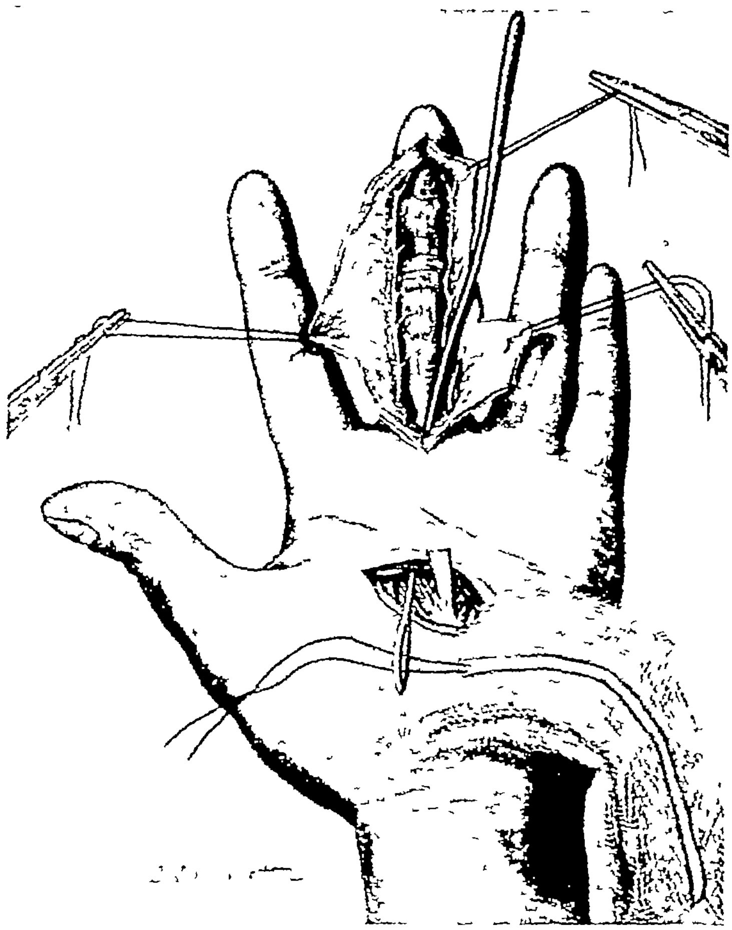


Fig 389 Tendon graft (long extensor tendon of third toe) being led through palmar incision into finger wound

now be checked by traction, because it is futile to extend a severely contracted flexor muscle with a graft and expect sufficient amplitude for full finger flexion If the sublimis tendon is to be used as a graft, and its proximal stump has been located in the palm, a third incision is made over the wrist. From this incision, the sublimis tendon is located, pulled out of the wound, and severed However, for reasons mentioned (p 729), the long extensor tendons of the toes (third and fourth) are preferred as grafts, while the palmaris longus tendon is next in line They are removed

rigid annular ligaments The long extensor tendons of the toes make excellent grafts since they are of small caliber and are surrounded by abundant gliding tissue To preserve the latter the tendon is exposed from a longitudinal curved incision along the dorsum of the foot The little toe does not possess a second extensor tendon hence its extensor tendon should not be used for tendon-grafting The palmaris longus or

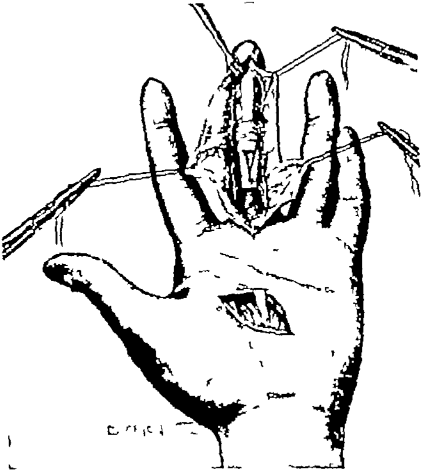


Fig. 388: Division of flexor tendons of third finger within tendon sheath. Exposure from bayonet incision proximal annular ligament is missing from palmar incision profundus tendon exposed and shortened to near insertion points of lumbricale muscles proximal sublimis stump has retracted proximally

the sacrificed sublimis tendon which is pulled through a separate transverse incision in the wrist is next in line of choice

Technic (Tendon Grafting for Replacement of Digital Flexor Tendons) (Figs 388–390 Cases 148 151 152 pp 1052 1055 1056) The distal tendon stump or stumps are excised i e. the sublimis slips are severed just beyond the proximal interphalangeal joint while a short stump of the profundus tendon is left at the terminal phalanx to be used later for anchorage of the graft (At this point the author advises the surgeon not to leave this stump too long, since it may become

In the majority of cases, owing to excision or destruction of the tendon sheath, a new annular ligament must be reconstructed to told the tendon in place over the volar surface of the finger This is done, according to Bunnell's plan, as follows (Figs 390, 391) Another tendon graft, available from the sources already mentioned, is passed around the proximal

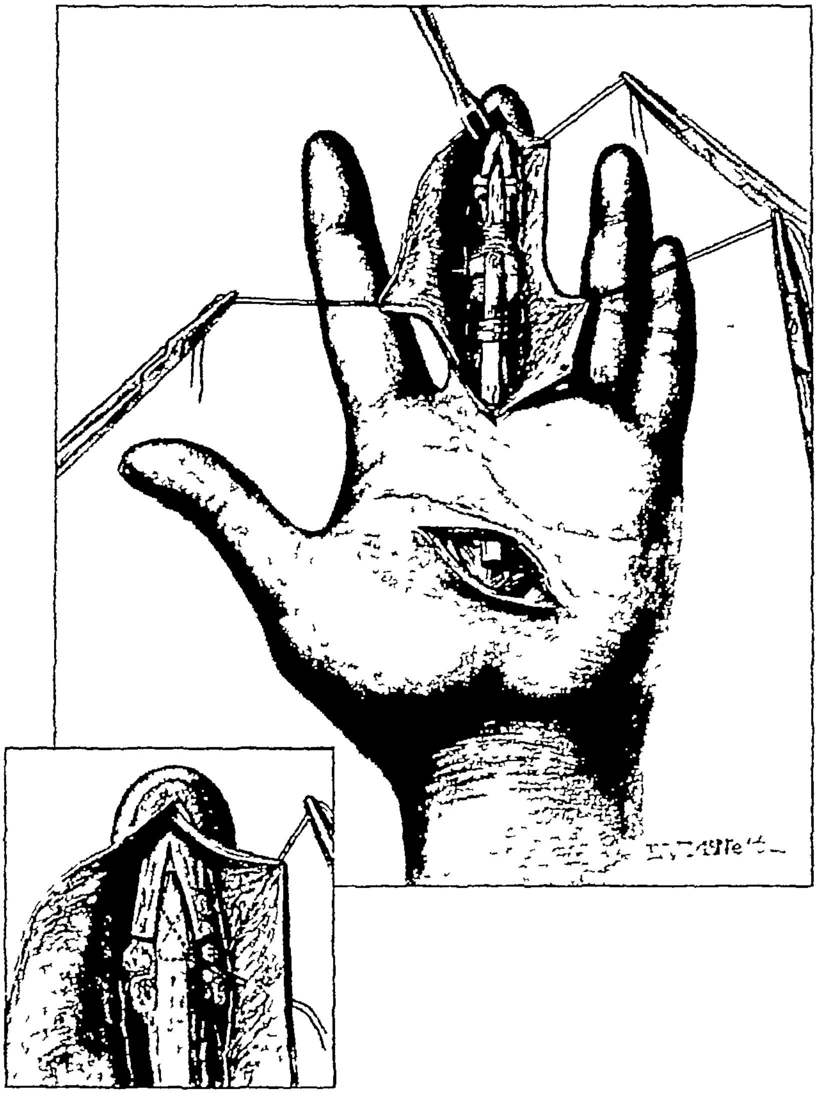


Fig 390 Fixation of tendon graft to terminal phalanx through drill hole in between slips of split distal end of profundus tendon, graft is armed with pull-out wire (see insert, also Fig 386, 391), additional fixation with mattress sutures through profundus slips and tendon graft, proximal annular ligament replaced with another tendon graft.

phalanx with a sharply curved aneurysm needle The tip of the aneurysm needle is kept in close contact with the bone so as not to include any of the digital vessels or nerves or the extensor tendon The ends of the new annular ligament are overlapped and sutured together The suture should come to lie at the side of the bone and not over the tendon Another

as described on p 729 great care being taken to remove them together with their gliding-tissue If those tendon grafts are used, the proximal stump of the sublimis is not sacrificed but fixed into the proximal stump of the profundus tendon its amplitude is greater than that of the profundus tendon, thus more motor power is added to the finger The graft is now tunneled through the palm as demonstrated in Fig 389 and anchored to the terminal phalanx.

This is done in one of two ways depending upon whether a distal profundus stump is present.

FIRST METHOD If there is no distal profundus stump at the terminal phalanx preserved for instance after subcutaneous rupture of the tendon Koch s method of sliding the graft around the terminal phalanx is excel lent. A sharply curved aneurysm needle is passed around the terminal phalanx the anchoring wires of the graft are threaded through the eye of the needle and needle and graft are withdrawn The graft is then united on the volar surface of the phalanx by an end to-side suture.

SECOND METHOD In those cases where a stump of profundus tendon is left at the terminal phalanx the writer has advised a modification of the Bunnell method (Figs 390 391) The profundus stump is shortened to a point just distal to the terminal joint. (For reasons explained p 729 it should not bridge the terminal joint) This short stump is split in half A hole is drilled through the terminal phalanx just beyond the split (Fig 391) The hole must be large enough to allow the tendon graft to pass snugly through it The canal is drilled obliquely to—but not through—the nail The tendon graft is now armed with Bunnell s pull-out wire (Figs. 386 390 *insert*) A fine stainless-steel wire (No 35) with a needle on each end is sewed in mattress-suture fashion and criss-crossing the ter minal 0.5 cm ($3/16$ inch) of the graft. To remove the wire later a second wire is threaded through the proximal loop of the suture wire Both ends of this wire are threaded together on a curved or straight needle and brought out through the skin proximal to the tendon insertion and left there This is the pull-out wire The two needles of the suture wire are passed through the bony canal and through the nail thus pulling the distal part of the graft into the bony canal The two ends of the suture wire are tied to a small roll of gauze or to a rubber button The terminal end of the tendon graft thus comes to lie within the bone and between the two slips of the profundus stump to which it is sutured with one or two mattress sutures of fine silk (Fig. 390, *insert*) Thus a bony and tendinous anchorage of the graft is achieved (The wire suture is removed after four weeks)

each other After a few days, the sutures will pull out Closure of the finger wound in layers follows Koch points out that it is a real advantage to be able to close the incision in the finger while the finger is still ex tended and before the suture of the graft to profundus stump in the palm is carried out It is a difficult task to close an incision extending along the greater part of the finger while the finger is supported in flexion and while one is attempting to avoid tension on a newly sutured tendon.

After the finger wound is closed, the proximal end of the graft is attached to the proximal segment of the tendon, with one of the customary tendon sutures The tendon junction should come to lie at the origin of the lumbricale at the profundus stump, so that this muscle may be used foi covering the junction In the thumb, the graft is sutured to the musculotendinous origin of the flexor pollicis longus at the wrist (Case 148, p 1052) The graft should be under moderate tension To follow Koch's advice, with the hand flexed at the wrist to an angle of from 120 to 110 degrees, with the fingers semiflexed at the metacarpophalangeal joints to an angle of 120 degrees, the ends to be united should come together at normal tendon tension If the flexor pollicis longus is the involved tendon, the amount of tension is that resulting from supporting the thumb in semiflexion at an angle of 120 degrees at interphalangeal and metacarpophalangeal joints and the hand in semiflexion at the wrist at an angle of 135 degrees

The remaining wound or wounds are closed in layers and the hand carefully supported until the immobilizing splint is applied

At this point, it should be noted that a tendon-grafting operation, tedious as it is, should not be carried out in a finger which has no sensation, and no return of sensation by repair of the digital nerves can be hoped for, since there is a tendency for the patient to use another finger with normal sensation in preference to the one which has been grafted

Reviews and follow-up examinations of large series of cases of flexor tendon-grafting have been reported on by Boyes, by Pulvertaft, and others, with good results in from 70 to 80 per cent of the cases

Dorsum of Hand: If proper splinting of the hand was carried out after primary repair of the original wound, it not infrequently occurs that an extensor tendon wound heals in the meantime, resulting in perfect function.

If, however, a secondary tendon repair becomes necessary, the proce duie is as follows The segments of the divided tendons are exposed from the scar of the former injury Lengthening the incision or making addi tional incisions—over the wrist, for instance—may be necessary for locat ing the retracted proximal segment (see also Primary Repair of Severed Tendons and Nerves). The tendons are carefully dissected free from sur

good method is applicable if one of the sublimis slips is available and fairly long and free of adhesions It then should not be sacrificed in the first phase of the operation but utilized at this stage The slip is laid across and over the graft and sutured to the other side of the proximal phalanx.

The next step is suture of the divided digital nerves with finest silk on an atraumatic needle At this point the use of a fat tissue graft should

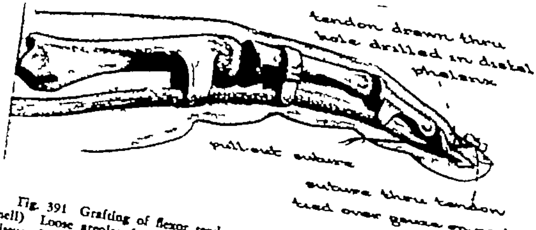
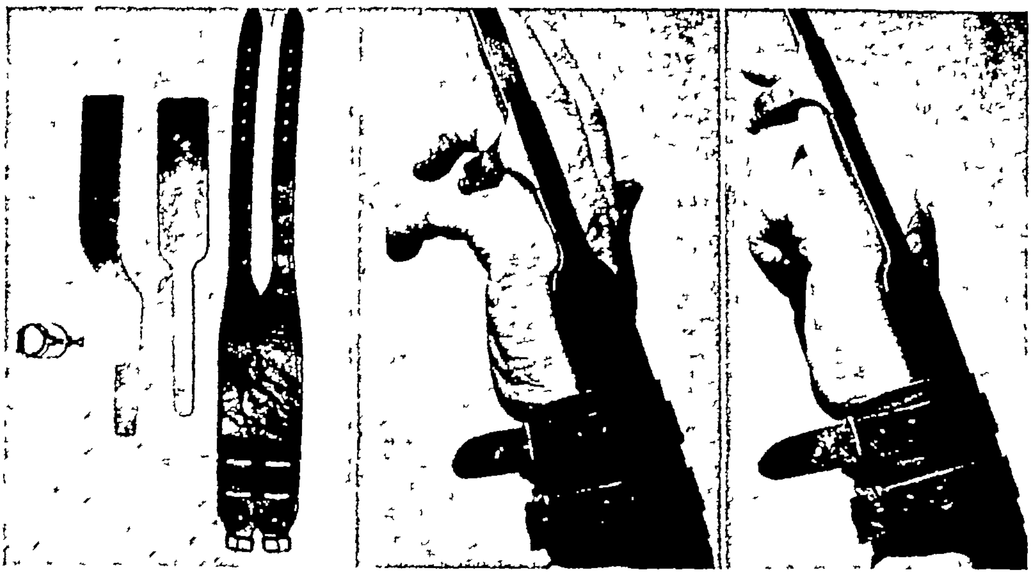


Fig. 391 Grafting of flexor tendon and reconstruction of annular ligament (Bunnell) Loose areolar fat tissue is wrapped around tendon graft to provide gliding tissue. Distal end of graft is fastened directly to bone Hole is made through terminal phalanx large enough to allow tendon graft to pass snugly through it. Canal is drilled obliquely from proximal part of volar surface of bone distal to but not through the nail. The holding suture of graft is made removable from outside Fine, stainless-steel wire needle on each end is followed in mattress-suture fashion through end of graft. To remove wire three weeks later second wire is threaded through proximal loop of suture wire and then its two ends are threaded together on straight needle and led proximad out through skin and left there. This is pull-out wire. Two needles of the suture wire are passed through bone canal and through nail, thus pulling distal part of graft into bony canal. Two ends of suture wire are tied over small roll of gauze or rubber button. Annular ligament is constructed with piece of tendon graft that is passed around phalanx with sharply curved aneurysm needle. Ends of new annular ligament are overlapped and sutured together Suture would come to lie at side of bone and not over tendon. Proximal end of tendon graft is sutured to proximal end of profundus tendon. (H. May: Surg., Gynec. & Obst.)

be mentioned. Such a graft becomes necessary in extensive cicatrization or exposure of bone To prevent adhesions between the tendon graft and bone a slippery piece of fat tissue—removed from the thin areolar veil like fat layer immediately overlying the fascia lata (see p 726)—is interposed These delicate tissues are awkward to suture in place but the following makes it easy (Bunnell) The fat graft is spread between tendon and bone each corner is tied to a thread of 000 plain catgut carried with a straight needle The needle is passed lateral to the phalanx to emerge at the dorsal surface of the finger where the opposite sutures are tied to

the conclusion that function during the first phase did not accelerate the development of the tendon callus On the contrary, early function appeared to be harmful so far as it caused more reaction of the surrounding tissue and weakening of the union Later on, however, after the first callus was formed, restricted use of the tendon caused but slight irritation with rapid increase in tensile strength of the union

It is the common belief among surgeons that motion, if started early, will prevent the adhesion of tendons. However, according to the fore-



a *b* *c*

Fig 392, *a* Finger splint which permits independent active exercises of interphalangeal joints of fingers

b Splint in use Flexor profundus tendon of fourth finger was replaced by tendon graft. When active exercises were instituted without splint, patient moved mainly joint which was movable before operation, namely, metacarpophalangeal joint. To force other joints to active exercises, splint is applied, clamp is slipped over finger and splint, holding the metacarpophalangeal joint immobilized Patient now moves first interphalangeal joint.

c Clamp immobilizing middle phalanx Patient can now exercise terminal joint (H May Surg, Gynec & Obst.)

going findings and the clinical experience of the majority of hand surgeons, the opposite seems to be the case It would seem to be substantiated that early motion, restricted or unrestricted, favors adhesions Iselin, however, who has admirably described the healing process of a tendon wound in the recent edition of his book and Pulvertaft believe otherwise Nevertheless, it can be said that adhesions are due not only to irritation of the surrounding tissue, but also to disturbance of the vascularization of the tendon This is a factor which should be pointed out strongly The bulk of the blood supply of a tendon outside its sheath is derived from the paratenon, or gliding-mechanism, which is

rounding scar tissue and if sufficiently mobilized, can ordinarily be brought together without undue tension The corresponding ends are fastened together with the usual tendon suture. If the proximal stumps were located from a separate incision the subcutaneous tissue between the incisions is tunneled and the proximal tendon segment pulled through (compare with Fig 389)

If a gap exists between the segments owing to contraction of the muscle bellies or to destruction of the proximal segment, the gap should be bridged with a tendon graft (Cases 140 153 154 pp 1040 1057 1058) The graft source is a long extensor tendon of a toe (For technic, see p 726 and following) The insertion of extensor tendon grafts should be quite tight as tight as the neighboring tendon is The metacarpophalangeal joint should be in 175-degree flexion with the interphalangeal joints in semiflexion If the gap happens to be in the extensor tendon of the third finger Mayer proposes to transfer one of the two extensors of the index finger to the third finger through a subcutaneous tunnel and to fasten it there to the distal tendon segment. If the gap happens to be over the middle phalanx of a finger the defect ordinarily does not need to be bridged. The extensor tendon divides here into three slips (see p 710) It rarely happens that all three slips are missing, and it is the author s experience that the two lateral slips or even one of them is sufficient to carry on most of the function there may be a moderate limitation of extension of the terminal phalanx left which however does not hamper the function of the hand seriously unless the lateral slips dislocate and need to be repaired according to a method outlined on p 741

If however the gap happens to be in the dorsal aponeurosis over the proximal phalanx or the proximal interphalangeal joint the gap must be bridged The graft to be used in this region is a piece of fascia lata with a thin covering layer of fat tissue attached. The graft is folded so that the two raw layers are upon each other The outside of the graft all around consists now of covering areolar fat tissue. A graft from the long extensors of one of the toes (see p 729) serves equally well Nerves if severed, are repaired after the tendons are sutured. The wound is now closed in layers.

After-Treatment

The healing process of a tendon wound passes through two stages the proliferative and the formative. The first stage lasts about two weeks During this time the tendon stumps become *united* by a connective tissue callus, which is then gradually converted into tendon Mason and Allen who did considerable experimental work on this subject came to

tures. If the patient fails to cooperate, continuation of splinting may be necessary The splint, however, should be removed temporarily every day for these exercises and electric treatment of the paralyzed muscles (see also p 593)

Complications· Occasionally after tendon-grafting, the flexor grafts attached to the terminal phalanx of the finger may pull loose If this is the case, immediate regrafting gives gratifying results Sometimes a patient is reluctant to exercise the repaired tendons on account of pain Daily median- and ulnar-nerve blocks promote flexion in the anesthetized finger Should the tendons become adherent, tenolysis should be performed after from six to eight weeks Tenolysis is carried out either (1) with a tendon-stripper from an incision over the wrist, followed immediately by active finger exercises (median- and ulnar-nerve blocks may be helpful) or (2) by exposing the tendon and, after tenolysis, wrapping the tendon in fat tissue (for source, see p 726)

Subcutaneous Injuries of Tendons

Subcutaneous ruptures of tendons follow direct or indirect trauma or are due to preexistent pathological processes In the majority of cases, the extensor tendons are involved, the flexor tendons, less often

RUPTURE OF EXTENSOR TENDONS

Rupture at Terminal Joint

The cause is usually a severe blow, which results in flexion of the extended distal phalanx The commonest seat is a tear of the dorsal aponeurosis at its insertion into the distal phalanx, usually with avulsion of bone The distal phalanx is flexed, and cannot be extended actively (so-called "mallet" or "baseball" finger)

The extensor apparatus over the distal finger joint is formed by the fused parts of the lateral slips, which, as extensions of the interosseous and lumbrical muscles, converge over the middle phalanx and insert into the joint capsule (Hauck) (see Fig 381) Hence, over the terminal joint, the extensor apparatus forms the main part of the joint capsule (Duncan) Its undersurface is lined with synovial membrane

There are two main types of mallet finger (Duncan) (1) Here, the tendon insertion of the dorsal margin of the base of the terminal phalanx is avulsed with a piece of bone—this can be diagnosed by x-ray examination (2) This is the nonfracture type, in which the tendon is ruptured from its base at the terminal phalanx or at a more proximal level (Fig 393) Regardless of the level of the rupture, there is always some damage to the joint capsule

in intimate contact with the surrounding tissue It is only natural that a tendon operation causes some disturbance of the local circulation, since it is almost inevitable to leave the intimate connection of the paratenon and surrounding tissue undisturbed If, however the involved tendon is adequately immobilized the interrupted blood supply of paratenon and tendon will become reestablished Early motion however may disturb vascularization leading to necrosis of the gliding mechanism and formation of adhesions

Hence it is advisable to immobilize a repaired tendon for three weeks The author prefers the molded plaster-cast splint to any other kind. The hand is placed in such a position that the suture lines are free or under a minimum of tension If flexor tendons are severed the maximum flexion should be at the wrist and the metacarpophalangeal joints The interphalangeal joints should be slightly flexed The thumb is held flexed in abduction and facing the fingers If extensor tendons are involved maximum extension should be at the wrist and the metacarpophalangeal joints If the thumb is involved it is held extended and abducted. Without removal of the immobilizing splint, the dressings are changed on the eighth postoperative day, and the sutures are removed Splint and dressings are removed on the twenty first postoperative day and motion should be started gradually the healed tendon is not subjected to full activity for at least two more weeks. After repair of the extensor tendons it is wise for the patient to wear the splint overnight during these two weeks during sleep the hand is clenched, causing a strain on the repaired tendons. Forearm and hand are placed daily in a warm saline bath and active motion exercises encouraged from the third week. Two weeks later local heat (baking warm water bath whirlpool bath) massage and passive exercises are added to the active exercises In addition to physical therapy occupational therapy is of great importance (p. 695—After Treatment) One of the author's patients developed a simple but effective splint for exercising those joints having limited motion while arresting motility of those joints that move freely The method is clearly depicted in Fig 592. Since this splint was introduced some of the author's patients have regained full motility of the fingers without needing other forms of physical therapy

If severed nerves were sutured at the time of the tendon repair the antagonists of the paralyzed muscles must be kept from contracting by intensive passive-motion exercises under supervision that is, the affected muscles must be kept continually relaxed until signs of regeneration are evident otherwise the paralyzed muscles would be overstretched by the uninjured antagonists resulting in delay of regeneration and in contrac

and is drilled into the first phalanx Pratt claims that if the point of the wire emerges centrally on the dorsum of the middle third of the proximal phalanx, the wire will have missed the flexor tendons Hence, the proximal interphalangeal joint should not be flexed too acutely The wire is then withdrawn until its point is just palpable beneath the skin of the dorsum of the proximal phalanx The distal end is cut off just beneath the skin of the finger The wire is withdrawn after four weeks Note two precautions First, the terminal joint should not be held in extreme hyperextension because of danger of necrosis of the dorsal skin One can notice the blanching of the skin of the hyperextended joint on one's own finger Secondly, if the intramedullary pin was placed in the wrong direction, do not remove this wire but use it as guide to insert a second wire

Amongst others Casscells and Strange have experienced occasional distressing, painful limitations of motions in the proximal interphalangeal joint after using Pratt's method Hence, they recommend placing the Kirschner wire only through the hyperextended distal joint, the proximal joint being maintained in 60 degrees of flexion by means of a plaster cast

In late cases, operative repair should be given a chance if the patient is anxious to have the deformity overcome and is aware of the possibility of failure

Technic. The joint is exposed from an L-shaped incision, the short arm of the "L" running just proximal and parallel to the base of the nail, the long arm at the posterolateral surface of the finger. After reflection of the skin flap, the site of the rupture is exposed If a piece of bone is attached to the avulsed tendon, a wire stitch is inserted into the end of the tendon close to the dorsal margin of the fragment The wire is then inserted through the terminal phalanx just beneath the site of avulsion by drilling a cutting edge needle through it, and tied In the nonfracture type, there is always some damage to the synovial reflection over the articular head of the middle phalanx The extensor tendon becomes firmly adherent to the neck of the middle phalanx, preventing the extensor tendon from acting on the terminal phalanx Hence, the tendon must be completely mobilized If it is not frayed and ruptured from its insertion near the terminal phalanx, it is fastened with a pull-out wire (see p 719) to the terminal phalanx The wire is led dorsally to the fingernail and tied to its rim (Fig 393) Insertion of a fat graft (see p 726) between tendon and bone and joint may be advisable to counteract adhesions If the tendon is ruptured farther distally or is frayed and must be excised, the gap is bridged with a tendon graft from the long extensor tendon

The prognosis of functional recovery after repair of a mallet finger is good only if treatment is applied within one week after the accident. It becomes progressively worse later on The treatment of choice during the first week is closed manipulation to restore the continuity of ruptured or avulsed tendon To achieve this, the terminal joint must be held in hyperextension and to make up for the retraction of the lateral bands the middle joint must be in moderate flexion The finger should be rigidly splinted in this position Thumb and finger are pinched together

Fig. 393 Mallet finger: Repair of extensor tendon with pull-out wire and insertion of intramedullary pin to splint terminal joint in extension and proximal interphalangeal joint in slight flexion.

to maintain the position (middle finger joint not too acutely flexed!) Then narrow wet strips of plaster of Paris are applied to the volar surface of the finger with cross strips placed across the dorsum just proximal to the joints (Smillie Bunnell) Pratt recently devised an ingenious method (Fig 393) Under digital nerve block a Kirschner wire (0 015 inch) is drilled through the tip of the finger and the hyperextended phalanx and terminal joint with the proximal interphalangeal joint held in 60-degree flexion the wire should then come to lie anterior to the middle phalanx

sensation of fatigue of arm and hand, making it impossible to use the hand in writing In some cases, a tremor of the entire hand is noted, which increases and makes an attempt at writing impossible These forms are characterized by the fact that the trouble appears only when an attempt has been made to write or soon after the beginning of writing, with no symptoms in the intervals

Treatment: The treatment consists in massage around the muscles of the extremity, particularly those of the hand Specially constructed braces should be worn while holding the pen The action between thumb and index finger may be eliminated, for instance, by the use of a bracelet encircling these fingers (Cazenave and Zabludowski) or the patient may be given a ring or ball for the palm of the hand, to which the pen is attached, the fingers pressing against the ball

DYSFUNCTION OF NEUROGENIC ORIGIN

Four examples are selected for discussion dysfunction following irreparable traumatic paralysis of (1) the nervus ulnaris, (2) the nervus medianus, (3) the nervus ulnaris and nervus medianus combined, and (4) the nervus radialis The extent of the dysfunction depends much upon the level of the nerve injury Severance of the radial nerve at the level of the wrist, for example, mainly causes loss of sensation, while that of the ulnar and median nerves at the same level is followed by sensory and motor disturbances The latter involve only the intrinsic muscles of the hand because the long flexors are supplied at a much higher level

We are indebted to Sterling Bunnell, among others, for the progress of surgery of the intrinsic muscles of the hand He summarizes the motor disturbances following paralysis of the intrinsic muscles as follows: With loss of action of the intrinsic muscles, the thumb cannot oppose or adduct It lies to the side of the hand The carpal and metacarpal arches are flat and the fingers are clawed (intrinsic minus hand, p 690) They cannot simultaneously flex in their proximal joints and extend in their distal two joints, and are practically devoid of lateral motion The hand has lost its skill and finer movements (Case 147, p 1050)

If the three nerves are severed higher up in the forearm or above the elbow joint, paralysis of the long flexors and extensors and other muscles are added, which will be described in more detail In cases where repair of the nerves is no longer possible, much of the imbalance can be corrected by tendon transfer and tendon transplantation

Certain fundamental requirements for a satisfactory tendon transfer must be mentioned Prior to the transfer, special effort must be made either to overcome an established contracture of the fingers and hand, or to

of one of the toes (See p 729) Ample gliding tissue should remain at tached to the graft The graft is sutured in place with a proximal and distal pull-out wire The placing of the wire sutures is facilitated by inserting them with the graft in situ Closure of the skin follows

After Treatment The finger is immobilized as described (p 739) Splinting is removed after four weeks and physiotherapy instituted

Rupture of Dorsal Aponeurosis over First Interphalangeal Joint

This rupture of the dorsal aponeurosis may be defined as a tear of its central slip The extensor tendon over the dorsum of the finger forms three slips (Fig 381) a middle one which is inserted to the joint capsule of the first interphalangeal joint and the base of the middle phalanx and two lateral slips which pass laterally to each side of the first inter phalangeal joints converge over the middle phalanx, and insert to the joint capsule of the second interphalangeal joint and the base of the distal phalanx The interosseous and lumbrical muscles fuse with the lateral slips. The function of the dorsal aponeurosis has been extensively studied by Hauck whose experiments and observations were confirmed by Mason If owing to a direct or indirect blow the dorsal aponeurosis ruptures over the first interphalangeal joint, the middle slip becomes detached from its insertion at the base of the middle phalanx and pulls away proxi mally the two lateral slips of the aponeurosis become disengaged and move from the dorsum laterally to a volar position The volar dislocation is increased by the pull of the lumbrical and interosseous muscles The joint protrudes between the displaced lateral slips as through a button hole The resulting deformity is typical extension or hyperextension of the distal interphalangeal and the metacarpophalangeal joints while the proximal interphalangeal joint is flexed (Case 155 p 1059)

Technic (Case 155 p 1059) From a bayonet incision the dorsal sur faces of the middle phalanx and of the first interphalangeal joint are ex posed. In recent cases the joint is found open while in older cases the rent of the capsule is closed by cicatricial tissue If the joint is open the rent is closed with interrupted silk sutures The lateral slips of the dorsal apo- neurosis are now dissected free from their volar position and moved to their normal laterodorsal position over the joint. In this position they are held together with interrupted transverse sutures of fine silk If the gap between the approximated slips is wide a dermal graft (see p 42) may be used to bridge the gap and to connect the slips The wound is closed with simple interrupted sutures.

prevent contracture by counteracting the pull of the antagonists Excision of the collateral ligaments in an effort to overcome hyperextension contracture of the metacarpophalangeal joints in interosseus muscle paralysis may further cripple the hand because severance of both collateral ligaments tends to throw the fingers into marked ulnar deviation Hence the collateral ligaments on the radial side should be left intact if possible thus enough relaxation can often be achieved to permit flexion without undue loss of stability (see p 694) Furthermore, a satisfactory and functioning muscle and tendon should be available for transplantation and scar tissue in the path of the transplant should be excised Flap transplantation to cover the resulting defect may become necessary

In addition to tendon transfer arthrodesis must be mentioned as a useful adjunct especially when there are not enough tendons available to stabilize certain joints in the position of function As a rule a proximal joint must be stabilized to permit the tendons on the distal joints to function (arthrodesis of base of thumb of metacarpophalangeal joints or any joint of any digit) A wrist arthrodesis in 30-degree dorsoflexion gives but little disability in addition out of six wrist muscles some could be made available to act on the digits.

Dysfunction after Irreparable Paralysis of Nervus Ulnaris

The ulnar nerve supplies the musculus flexor carpi ulnaris flexor digitorum profundus of the fourth and fifth fingers the musculi interossei (three palmar and four dorsal) the musculi lumbricales of the fourth and fifth fingers the ulnar half of the flexor pollicis brevis the adductor pollicis, and the muscles of the hypothenar eminence

The deformity following low ulnar nerve palsy is usually referred to as clawhand (Duchenne) or intrinsic minus hand (Bunnell p 690) Dean Lewis describes it as follows Normally the lumbricales acting through the common extensor tendon cause flexion of the first phalanx and extension of the last two phalanges (Fig 381) When these muscles are paralyzed the antagonistic muscles act, causing *extension of the first* phalanx and partial flexion of the last *two phalanges* (compare with Case 147 p 1050) The palmar interossei muscles adduct the fingers toward the middle finger *while the dorsal interossei abduct from the same finger* As a result of paralysis of the interossei *the fingers can no longer be adducted or abducted* Abduction of the little finger is *impossible* All the symptoms from loss of function of the interossei are more pronounced in the fourth and fifth fingers than in the second and *third* for in these the lumbricales still function (see also p 690)

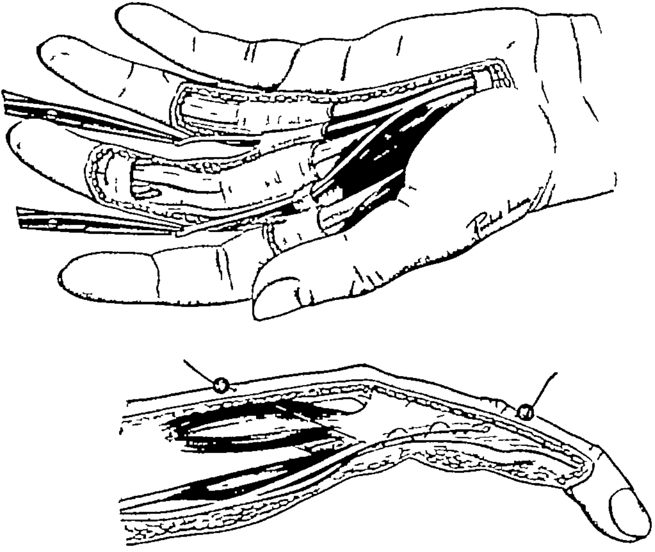


Fig. 394 Operation to restore normal balance in fingers in claw hand from paralysis of interosseus and lumbricalis muscles. The tendon of each flexor digitorum sublimis is split, transferred through a lumbrical canal and fastened to a lateral band of a dorsal aponeurosis by a removable stainless steel wire either by the pullout stitch or the running suture method. (S. Bunnell, Surgery of the Hand, J. B. Lippincott Co.)

may hinder withdrawal and if so must be divided) With the back of the knife the slips are slit further apart for about 3 cm ($1\frac{3}{16}$ inches) or longer The end of the slips are criss-crossed with a thin wire suture which acts as a guide A probe is now passed from the palmar incision through the lumbrical canal. The wire of the corresponding sublimis slip is threaded through the eye of the probe and withdrawn through the finger incision a similar procedure is performed with the other slip The transverse fibers and lateral band of the extensor mechanism (see Fig 381) are located in the finger wound The metacarpophalangeal joint and wrist are semiflexed and the sublimis slip is led through the transverse fibers and lateral band to the dorsal surface of the lateral band. The contiguous surfaces of the lateral band and sublimis slip are scraped to favor adhesions between the two structures Both are now fastened together either by a removable running wire suture (after Bunnell) or with five silk sutures The same procedure is performed on the other side of the finger followed by closure of the wound and application of a dorsal molded plaster-cast splint for three weeks

In case of claw deformity of the fifth finger the sublimis slips of this finger are used to overcome the muscle imbalance Here however it is sufficient to anchor both slips together on the radial side of the finger

Technic. *In High Lesions of Ulnar Nerve* In lesions of the ulnar nerve above its branches to the flexor profundus of the fourth and fifth fingers the sublimis of the third finger must be used since sacrificing the sublimis tendon of the fourth and fifth fingers in which the flexor profundus muscles are paralyzed would only add markedly to the dysfunction One slip of the sublimis tendon of the third finger goes to the radial side of the ring finger and one to the radial side of the fifth finger The results however are not as good as when the sublimis tendon of the involved finger is transplanted to the extensor mechanism of the same finger (Luckey and McPherson) Restoring the function of the paralyzed flexor profundus muscles of the fourth and fifth fingers by joining them with the flexor profundus of the third finger has been advocated. This procedure however should be avoided since it increases the deformity due to muscle imbalance. With the sublimis tendons functioning and the metacarpophalangeal joints stabilized after the tendon transfer moderately good flexion of the fourth and fifth fingers is possible

If the second to the fifth fingers are clawed as in combined lesions of the ulnar and median nerves, the technic described on p 761 should be followed

Paralysis of the first interosseus muscle or abductor of the index finger as caused by ulnar or local lesions may result in weakness of opposition

muscle, the T is drawn to a Y, drawing the thumb and fifth metacarpal toward each other and restoring the arches The cross-member lies in soft movable tissue behind the profundus tendons, and can be drawn proximally without resistance

Technic (Bunnell) (Fig 395) *Restoration of Adduction of Thumb* The fifth metacarpal is exposed in its ulnar volar aspect just proximal to its head One end of the tendon graft (one of the long extensor tendons of the toes, see p 729) to be used as cross-tendon is fastened to it under a chipped flake of bone (Fig 395, *B*) It is anchored with a thin wire suture, to which a pullout wire is attached, as described on p 719 The tendon wire escapes through the skin of the back of the hand over the dorsoradial aspect of the fifth metacarpal, and is tied over a button The pullout wire is placed on the opposite side The palm is now opened by an incision paralleling the longitudinal crease The flexor tendons are visualized through this incision With a suture-carrier (see Fig 59), the other end of the tendon graft is passed across through the palm behind the flexor tendons, and is made to emerge through a small lateral incision over the ulnar aspect of the base of the proximal phalanx of the thumb Here it is fastened in a manner similar to that described on p 727 and depicted in Fig 387, the wires are passed through the phalanx and thumb and tied over a button The pull-out wire is placed on the opposite side The tendon should be slack when the hand is fully spread, since grafts shrink a little From the mid-palm incision, either the tendon of the musculus palmaris longus, with its prolongation of palmar fascia, or a sublimis tendon—one, of course, which has not been used in the first step of the operation (see foregoing remarks on claw deformity)—is severed at the proper level and then looped around the center of the cross-tendon, embedding it in and suturing it to itself, one stitch is placed to keep it from sliding along the cross-tendon The wounds are closed

Littler's suggestion of utilizing a sublimis tendon, if such is available, to restore the palmar and thumb arches is a good modification of the Bunnell T-operation The sublimis tendon is severed near its insertion, withdrawn through an incision in the palm, and split in two strands One strand is attached to the adductor pollicis insertion and the other to the base of the proximal phalanx of the little finger on its ulnar aspect This procedure simulates the tendon T-operation of Bunnell or the entire tendon may be sutured only to the adductor insertion of the thumb

After-Treatment· Forearm and hand are immobilized on a dorsal molded plaster-cast splint for three weeks. Immobilization is then discarded, sutures and wires are removed, and physiotherapy is instituted

insertion of the first dorsal interosseus muscle Fixation and after treatment are described above.

Restoration of the adductor power of the thumb as already pointed out may not be warranted if the long flexors are functioning and good apposition of the thumb is present or can be restored as in combined lesions of ulnar and median nerves If restoration of adduction of thumb and little finger and of the carpal and metacarpal arches becomes necessary Bunnell s tendon T-operation is the choice (Fig 395) It consists of

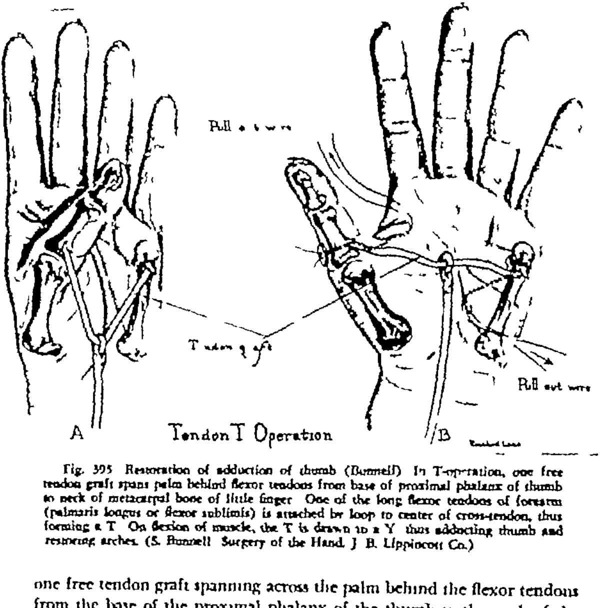


Fig. 395 Restoration of adduction of thumb (Bunnell) In T-operation, one free tendon graft spans palm behind flexor tendons from base of proximal phalanx of thumb to neck of metacarpal bone of little finger One of the long flexor tendons of forearm (palmaris longus or flexor sublimis) is attached by loop to center of cross-tendon, thus forming a T On flexion of muscle, the T is drawn to a Y thus adducting thumb and restoring arches. (S. Bunnell Surgery of the Hand. J B. Lippincott Co.)

one free tendon graft spanning across the palm behind the flexor tendons from the base of the proximal phalanx of the thumb to the neck of the metacarpal of the little finger One of the long flexor tendons of the forearm such as the sublimis or palmaris longus is attached by a loop to the center of the cross tendon thus forming a T On flexion of the

don, may be looped through the short muscle and tendon attachment to the pisiform bone and sutured to itself, so that it forms a circle 2 cm (3/4 inch) in diameter. The sutured junction is then slipped around until it is within the muscle Another method of making a pulley is to use one half of the thickness of the flexor carpi ulnaris tendon, severing one of the halves high and suturing this free end to the ligament of the pisiform bone to complete the loop Similarly, the tendon of the musculus palmaris longus may be severed 4 cm (1 5/8 inches) above its insertion and made to act as a loop or pulley by suturing it into the pisiform ligamentous tissue, leaving its original insertion intact Instead of constructing a pulley, one may pass the tendon used around the flexor carpi ulnaris tendon and on to its insertion in the phalanx of the thumb

Incisions, if possible, should be made along skin-tension lines They should, however, *not directly overlie tendons after rerouting* Finding the proper plane of rerouting is important This plane lies just superficial to the palmar fascia, and should be deep enough in respect to the skin itself so that the tendon does not become adherent to overlying skin

The most useful variations will be described in detail Among others, Kirklin and Thomas, Luckey and McPherson, Royle, Thompson, Littler, Riordan, Phalen and Miller, have contributed much to the success of the original methods

The procedure of choice, since it is the most physiological method, becomes possible if a sublimis tendon, preferably of the fourth finger, is available for activation The tendon is rerouted through a pulley at the pisiform bone, subcutaneously to the dorsal aspect of the proximal phalanx of the thumb, and fastened to the abductor pollicis brevis Normally, this muscle is the most important one of the thenar group By virtue of its insertion into the lateral part of the base of the proximal phalanx of the thumb and into the long extensor tendon, the abductor pollicis brevis can stabilize the metacarpophalangeal joint in abduction, flexion, and pronation—and can assist extension of the terminal phalanx —the essential functional components of opposition Hence, good results are obtained by suturing one slip of the transferred sublimis tendon to the tendinous insertion of the paralyzed abductor pollicis brevis (Littler), the other one into the long extensor for additional stabilization (Riordan)

Technic (Fig 396) From an incision just distal and parallel to the volar crease of the metacarpophalangeal joint of the fourth finger, a short transverse incision is made through the flexor sheath, and the slips of the sublimis tendon are isolated The finger is then flexed in the first interphalangeal joint, and the slips are severed From a transverse incision

Dysfunction after Irreparable Paralysis of Nervus Medianus

The median nerve supplies the musculus flexor *digitorum* sublimis and musculus digitorum profundus of the second and third fingers the musculus pronator teres and pronator quadratus the musculus flexor carpi radialis and flexor pollicis longus the musculus abductor pollicis brevis the radial head of the flexor pollicis brevis the musculus opponens pollicis and the two radial musculi lumbricales The disability following division of the median nerve is not great, even if the median *nerve is severed* in the cubital region since its motor branches enter the long flexors high in the arm The greatest disability is due to loss of *opposition of the thumb* with the other fingers and loss of sensation (see also p 744) Atrophy of the thenar eminences usually develops early and is *striking The thumb can no longer be rotated to* face the fingers The pincerlike action of the thumb resulting from its opposition with the other fingers adds much to the *efficiency of the hand The thumb to* be in true opposition must be opposite the fingers that is the pulp of the thumb must face that of the fingers and the thumbnail must be parallel to the volar surface of the fingers If this function is lost from irreparable nerve damage it can be restored by tendon transplantation (compare with Case 156 p 1060)

Bunnell stresses that two essential principles must be adhered to direction of pull and correct insertion of the tendon graft to give pronation Quoting Bunnell

1 The tendon from its insertion in the thumb should pass subcutaneously in the direction of the pisiform bone so that it will pull the thumb in the correct direction and the insertion of the tendon should be on the dorso-ulnar aspect of the base of the proximal phalanx of the thumb so as to restore the pronatory component.

2. To make the tendon pull toward the pisiform bone either a tendon pulley is constructed there or the tendon is looped around the distal part of the tendon of the flexor carpi ulnaris. There will then be a similar arrangement to that found anatomically in the omohyoid or the tensor veli palatini muscles

Bunnell offers a varied choice in the selection of muscle and tendon and the reconstruction of the pulley depending on which are available or advantageous in the particular case of reconstruction

For motor power the musculus flexor *carpi ulnaris* the musculus palmaris longus the musculus flexor digitorum *sublimis* of the ring finger or any other available long flexor muscle may be used.

In regard to tendons various combinations are depicted in Fig 396

For the construction of a pulley at the pisiform bone a free tendon graft either from the palmaris longus or from any other *available ten*

In some cases, extensive scarring on the volar side of the wrist may make the Bunnell type of opponens transfer difficult As already stated in the discussion of the Bunnell procedure, the motor tendon is rerouted proximal to the transverse ligament, and some sort of pulley in the repair of the pisiform bone is employed In modifying Royle's operation,

Fig 396 Sublimis tendon transfer (of fourth finger) to restore opposition of thumb in irreparable median nerve palsy Flexor carpi ulnaris used as pulley One slip of sublimis tendon is threaded through loose ligaments between abductor tendon and bone, i e, proximal to metacarpophalangeal joint. The other clip is led beneath the extensor pollicis longus tendon and through a perforation of the same, 2 cm (0 79 inches) distal to the metacarpophalangeal joint, it is then slung dorsally around the tendon to be united with the other slip, either end to end with one of the usual tendon sutures or by overlapping the ends of the slips

Thompson withdraws the sublimis tendon through a longitudinal incision at the radial side of the hypothenar eminence in the palm, in other words, distal to the transverse carpal ligament He then reroutes the tendon subcutaneously across the palm to the thumb In this instance, the palmar fascia, around which the tendon is rerouted, acts as a pulley This procedure is preferred if the wrist and forearm are scarred, since all transfer can be performed in normal tissue without entering scarred areas

over the insertion of the flexor carpi ulnaris the latter is isolated From the same incision the severed sublimis tendon is withdrawn (the chiasm of Camper may hinder withdrawal and if so must be divided) It is now passed beneath around and over the flexor carpi ulnaris tendon This is the simplest and most satisfactory pulley The flexor carpi ulnaris tendon should not be mobilized during this procedure for this would allow it to bow radially If the flexor carpi ulnaris is not available as a pulley a pulley must be constructed from a free tendon graft, either from the palmaris longus tendon or from one of the toe extensor tendons (Fig 397 *A D*) The graft is looped around the short tendon attachment distal to the pisiform bone and sutured to itself so that it forms a circle 2 cm ($1\frac{3}{16}$ inch) in diameter The sutured junction is then slipped around so that it will not be in contact with the transferred sublimis tendon An inverted hockey stick incision is made on the dorsoradial side of the thumb starting just proximal to the distal joint and ending on the radial side proximal to the metacarpophalangeal joint. A fascia-carrier (Fig 55) (or uterine-packing forceps) is inserted through this part of the incision and pushed subcutaneously through the incision at the wrist. The sublimis tendon slips are crisscrossed with a fine wire suture of stainless steel the wire is threaded through the eye of the fascia-carrier and withdrawn through the incision at the thumb The tendon is led through a slit in the fascia overlying the abductor muscle One slip of the tendon is threaded through the loose ligaments between the abductor tendon and the bone The other slip is led beneath the extensor pollicis longus tendon which is perforated about 1 cm ($\frac{3}{8}$ inch) distal to the meta carpophalangeal joint, and through this perforation the slip is slung dorsally over the tendon to be united with the first slip All wounds are then closed.

After Treatment The thumb must be immobilized in the position of abduction and opposition and slight flexion of the metacarpophalangeal joint this is best achieved by taping the opposed tips of the thumb and the fifth finger together thus holding them in correct position while a dorsal molded plaster-cast splint is applied The latter must include the slightly flexed wrist the knuckles and the entire thumb The other fingers are left free and should be moved as soon as patient is awake The immobilization is removed after twenty-one days Semi immobilization is then applied by adhesive rubber band traction which pulls the proximal phalanx of the thumb toward the pisiform bone It is explained to the patient which tendon has been rerouted as the motor tendon and he is urged to practice with this tendon After one week the adhesive traction is removed and the patient is allowed to move the wrist.

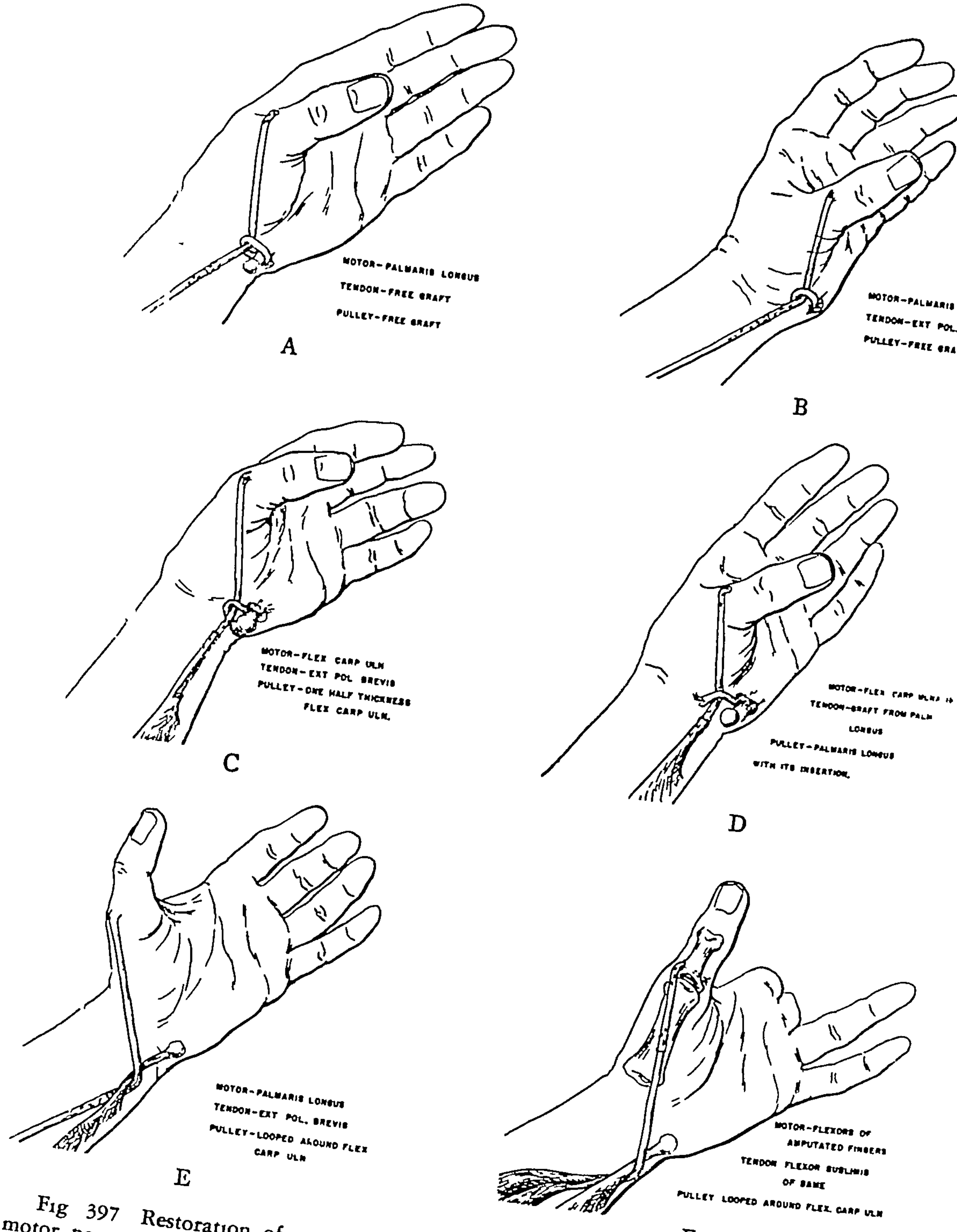


Fig 397 Restoration of opposition of thumb (Bunnell) Various combinations of motor power, tendon transfer, and construction of pulley (S Bunnell Surgery of the Hand J B Lippincott Co)

If one of the sublimis tendons is not available the next best method is the use of the flexor carpi ulnaris as motor power a pulley of one-half thickness of the flexor carpi ulnaris tendon at the pisiform bone and the extensor pollicis brevis tendon as a means of prolonging the motor power

Technic (Bunnell) (Fig 397 C) From a curved incision ulnar to the insertion of the flexor carpi ulnaris of the pisiform bone the flexor carpi ulnaris tendon is located It is split in half beginning at the pisiform bone The ulnar half is severed proximally and it is used to make the pulley the latter should have a circle of 2 cm. (1$\frac{3}{10}$ inch) and the loop should be formed so that the outer surface of the tendon slip forms the inner circumference of the circle to prevent adhesions within the pulley The free end is sutured to the ligament of the pisiform bone. The radial half of the carpi ulnaris tendon is severed from the pisiform bone to be used as the active tendon

The insertion of the extensor pollicis brevis tendon is located from a small curved incision over the radial aspect of the metacarpophalangeal joint Through another incision over the radial aspect of the wrist, the musculotendinous junction of the musculus extensor pollicis brevis is located and the tendon severed at that point. The tendon is now withdrawn through the distal incision of the thumb and guided with a fascia carrier (Fig 55) or uterine packing forceps through this incision subcutaneously toward the pisiform bone The free end of the tendon is looped through the pulley with the thumb in abduction and opposition this free end is sutured to the flexor carpi ulnaris tendon by interweaving or by end to-end suturing

After Treatment See p 753

When this method is used a few technical details are of importance and they have been aptly pointed out by Kirklin and Thomas First an accurate localizing and recognition of the extensor pollicis tendon are necessary In a few patients the tendon is absent If this is so the prolongation must be made with a free graft either from the palmaris longus or from one of the extensor tendons of the foot. The free end of the graft is attached to the thumb as shown in Fig 397 *D* If the tendon is present it must be dissected out in such a manner that when it *is pulled* upon in the direction of the pisiform bone it produces satisfactory opposition of the thumb If it is dissected too far distally across the metacarpophalangeal joint of the thumb it will markedly flex this joint and this is undesirable In a few instances if the tendon is not dissected far enough distally it will hyperextend this joint Therefore dissection must be carried out to just such a point that the desired rotation and opposition are obtained without either of the aforementioned undesirable actions.

three digits together with one stainless-steel suture A groove is chiseled into both articular bones and a matchstick-size inlay bone graft placed across the joint The bone graft is taken with chisels from the subcutaneous border of the ulna or tibia For better stabilization, a short Kirschner wire is drilled into the marrow through the proximal half of the first metacarpal and the greater multangulum, greater stabilization can be achieved by cross-pinning the first and second metacarpals (compare with Case 159, p 1064), all wires are placed subcutaneously A cast is applied with the hand in the position of function

If, aside from the contracture of the first carpometacarpal joint, the surrounding soft tissues are rigidly contracted, the bone-bloc operation has a better chance to overcome the deformity (see below)

If the first carpometacarpal joint is obliterated by bony fusion, a metacarpal osteotomy is performed (see below)

If the first metacarpophalangeal joint or the terminal joints of the thumb are contracted in malposition, arthrodesis of these joints is indicated After removal of the articular surfaces from a longitudinal, dorsal, tendon-splitting incision, the joint surfaces are brought into 25-degree flexion, they are held together by an inlay bone graft (except in the terminal joint) (bone graft to be taken from subcutaneous border of ulna or tibia) and an intramedullary cross-pinning of the joint by a short, subcutaneously placed Kirschner wire (compare with Fig 398) This is followed by immobilization with a dorsal molded plaster-cast splint for from about four to six weeks (See also p 778)

Osteotomy: When the carpometacarpal joint is fused in malposition of the thumb, osteotomy is performed through the proximal third of the first metacarpal from a dorsoradial incision The thumb is rotated into opposition A small wedge of bone may need removal to permit smooth fitting of the fragments The latter are held together by intramedullary cross-pinning of the fracture line, by cross-pinning the first two metacarpals (compare with Case 159, p 1064), and by immobilization in a plaster cast for from about four to six weeks

Intermetacarpal Bone-Grafting (Case 139, p 1039) This operation, first devised by Foerster and later elaborated on by Thompson, Brooks, and others, is indicated in permanent paralysis of abduction and opponens muscles for which tendon transplantation to restore active opposition cannot be performed or in spastic cases with adduction contracture or in post-traumatic and postinfection cases with rigid scar contracture Prior to the bone-grafting operation, any fixed adduction contracture, particularly of the skin, must be overcome Stripping of the contracted adductor and interosseous muscles and removing all scar tissue in the

Occasionally also a slip connecting this tendon to the extensor pollicis longus must be severed so that it does not exert an extending action on the distal phalanx In some cases, despite severance of all connections to the long extensor tendon of the thumb, the extensor pollicis brevis continues to extend the distal phalanx In these situations it is probably best not to utilize this tendon but to use a free tendon graft for prolongation of the motor power

Instead of the flexor carpi ulnaris the palmaris longus or the extensor carpi ulnaris may be used as motor muscles If the palmaris longus is used the flexor carpi ulnaris tendon will serve as a pulley If the extensor carpi ulnaris is used no pulley is necessary The direction of pull after rerouting from the extensor side to the flexor side is toward the pisiform bone (Case 156 p 1060)

High Irreparable Lesions of Nervus Medianus In these lesions in addition to restoring opposition of the thumb the flexor action of thumb index finger and middle finger must be restored The flexor pollicis brevis however is often supplied by the ulnar nerve and may therefore be spared in complete median palsy (Highet, Rowntree) Stiles and Forrester recommend transferring the extensor pollicis brevis to the flexor pollicis longus splitting the extensor carpi radialis longus in two and transferring it to the profundus tendons of index and third fingers (see also p 761) If the extensors are not available Forrester recommends the following procedure From an L-shaped incision along the flexor creases of the wrist and the radial side of the forearm the flexor pollicis longus tendon and the profundus tendons of the second and third fingers are severed proximally and inserted through buttonholes into the profundus tendons of the fourth and fifth fingers (in a way similar to that depicted in Fig 400) Opposition of thumb is restored as described in the foregoing discussions

Bone and Joint Operations to Restore Opposition of Thumb Whenever rotation of the thumb is markedly restricted from ankylosis of the joints or contracture or tendon transfer cannot be performed to restore active opposition of the thumb rotation osteotomies arthrodesis and the bone bloc operations are good methods to hold the thumb permanently in the position of function

Arthrodesis If the carpometacarpal joint of the thumb is cicatricially contracted while the surrounding soft tissues are not contracted, arthrodesis of this joint with the thumb in abduction and opposition is performed The joint is exposed from the radial side the articular surfaces are removed and the thumb is placed in the position of function This position is temporarily maintained best by fastening the pulps of the first

system is activated by utilizing the sublimis tendons sublimis 2, both slips for index finger, sublimis 3, for third and fourth fingers, sublimis 5, both slips for fifth finger, sublimis 4, for opposition of thumb The tendons are withdrawn at the wrist (the chiasm of Camper may hinder withdrawal, and if so must be divided) The slips are split further apart with the back of the knife, then passed from the wrist through the lumbrical canals, and fastened to the dorsal aponeurosis and lateral bands of the fingers, with the wrist and metacarpophalangeal joints flexed (Littler, Brand) (see also p 746 and Fig 394) The strands are fastened on the radial sides of the fingers, except for the index finger, where an abductor transfer is necessary In this case, the sublimis strand is not passed through the lumbrical canal, but sutured to the lateral band on the ulnar side of the index finger, where it serves to adduct and flex the metacarpophalangeal joint and to assist in extension of the interphalangeal joints

If a sublimis tendon is not available or if the intrinsic paralysis has had long duration, Fowler uses the extensor proprius of the index and fifth fingers by rerouting them volar to the transverse metacarpal ligaments From a dorsal longitudinal incision between the metacarpal heads of the index and third fingers, and the ring and fifth fingers, the proprius tendons are exposed and severed from their insertion and split in two strands The fingers are then flexed in the metacarpophalangeal joints, and each strand is passed volarward to the transverse metacarpal ligaments One strand of the extensor indicis proprius is fastened to the lateral band of the ulnar side of the index finger and the other one to the radial lateral band of the third finger Of the extensor quinti proprius, one strand is passed to the ulnar lateral band of the fourth finger and the other to the radial lateral band of the fifth finger

If the middle and terminal phalanges cannot be extended by the long extensors when the metacarpophalangeal joints are stabilized in midflexion, a tendon transfer to the lateral bands of the proximal phalanx will not be sufficient In these cases, it is necessary to strengthen the weakened long extensor tendons, aside from supplying the checkrein on the extension of the metacarpophalangeal joints (with sublimis transfers) This is best done by Fowler's method The transferred tendon (the flexor carpi radialis longus, for instance, lengthened by free tendon grafts from the long extensor tendons of the toes) is led through the lumbrical interosseous canal of each side of the finger, over the dorsum of the proximal interphalangeal joint, into the converging lateral bands of the middle phalanx, here, tendon and bands are sutured to each other

All these tendon transfers should not be performed in one stage Restoration of abduction of the index finger and activation of the in-

cleft and the cicatricial web may necessitate transplantation of an abdominal flap as a preliminary step If this is not necessary the operation is performed in one stage The bone graft taken from the crest of the ilium and wedge-shaped is inserted through an incision along the web If the muscles in the web are contracted they are stripped or excised and the bone graft is driven between the first two metacarpals (Frackelton) The opposing bone surfaces of the latter should be roughened with a chisel prior to the wedging The thumb is placed in the position of function This is best achieved by temporarily fastening the pulps of the first three digits together with one stainless-steel suture The bone graft is held in place with a Kirschner wire drilled from a small incision over the radial side of the first metacarpal through the latter and bone graft into the second metacarpal The wire cut flush with the bone and the wound edges are sutured over it. Plaster-cast immobilization is not necessary

Dysfunction after Irreparable Paralysis of Nervus Medianus and Nervus Ulnaris

Combined Irreparable Median and Ulnar Lesions at Wrist Level The dysfunction following a combined injury of median and ulnar nerves at the level of the wrist is mainly from loss of sensation and of function of the intrinsic system This is because the long flexors are supplied at a much higher level Loss of sensation and early pulp atrophy are severe disabilities in themselves They become aggravated by clawing of the fingers by loss of opposition of the thumb and by finger extension The thumb lies at the side of the hand it can neither oppose nor adduct. The fingers are hyperextended in the metacarpophalangeal joints and flexed in the interphalangeal joints (intrinsic minus hand p 690) They can not simultaneously flex in their metacarpophalangeal joints and extend in the interphalangeal joints they have no lateral motion The carpal and metacarpal arches are flat the thenar region is atrophied and the dorsal aspect of the thumb web is hollow (Case 147 p 1050) (see also p 744)

The motor dysfunction can be much *improved* by tendon transfer It is again pointed out that contracture must be absent or overcome (see also p 745) Opposition of the thumb is restored as already described If a sublimis tendon is available it is used as a motor (see p 752) otherwise one may use the flexor carpi ulnaris (*see p 755*) The bone bloc operation and arthrodeses are indicated (see pp 757–758) only in rigid adduction contractures Abduction of the *index* finger is preferably overcome by transfer of the extensor pollicis brevis A sublimis tendon should not be used for this purpose such *tendons* are better used for restoring thumb opposition and intrinsic action The paralyzed intrinsic

permit the distal joint to extend to about 160 degrees If the tension is too great, there will be excessive clawing, and the thumb and fingers will not come together in a functional position On the other hand, excessive length will allow complete extension, but will not permit enough flexion for a satisfactory grasp

ARTHRODESIS OF WRIST

During the foregoing reconstructive program, primary arthrodesis of the wrist is essential Arthrodesis permits the subsequent borrowing of the extensors of the wrist (extensor carpi ulnaris, extensor carpi radialis, longus, and brevis) for transplantation into the flexors of the digits In

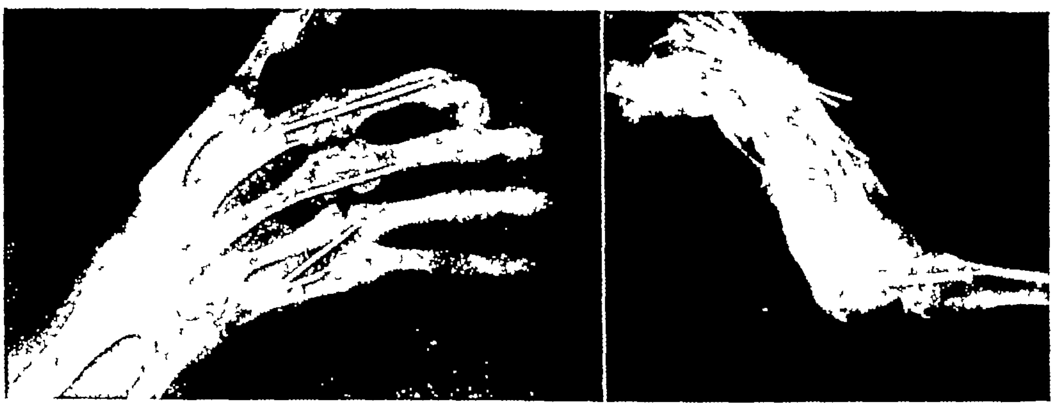


Fig 398 Arthrodesis of wrist and metacarpophalangeal joints of fingers in patient with irreparable median and radial palsy Wrist fusion done first (after Robinson-Kayfetz), followed by fusion of metacarpophalangeal joints (see p 778) three months later Pins gradually worked themselves out Screw was removed after nine months This roentgenogram shows result seven months after wrist fusion (four months after metacarpophalangeal joint fusion)

most methods of arthrodesing the wrist, the carporadial joint is fused—usually with bone grafts (Abbott et al) —while the carpometacarpal joints are not fused, thus adding strength to the grasp of the hand To shorten the healing-process by avoiding bone-grafting, Robinson and Kayfetz have developed a method which consists in resecting the proximal row of carpal bones, with fixation of the capitate to the radius by means of a screw In this way, viable cancellous bones, with an intact blood supply, are opposed to one another, and the internal fixation provides a positive means of maintaining position Cancellous grafts are used to reinforce the fusion, but healing is not dependent upon any grafted bones In twelve arthrodeses, all successful, the average immobilization time was eight weeks The author has found this method particularly useful in contracted wristdrop, where the contracture could not be overcome by simple stretching

Technic (Robinson and Kayfetz) (Fig 398) Starting over the dorsal aspect of the distal third of the ulna, a bayonet incision is made over the

trinsic system of the second to the fifth fingers make one stage restoration of thumb opposition makes another

If there is marked hyperextension of the metacarpophalangeal joint of the thumb adduction must also be restored (see p 750)

Combined Irreparable Median and Ulnar Lesions above Forearm High combined lesions of median and ulnar nerves cause a severely disabled hand Aside from lack of sensitivity which in itself is a great handicap the intrinsic and long flexor muscles are paralyzed. Even if function of all long flexors could be restored without the intrinsic muscles they are useless from the point of view of function Yet some usefulness can be restored to the hand by transfer of extensor tendons to the flexors of the hand To permit use of all extensor tendons the wrist should be fused (for technic, see p 762) Arthrodesis of the metacarpophalangeal joints may also be considered (p 778) However before the wrist is fused the opponens transfer (utilizing the extensor carpi ulnaris as motor see p 757) should be carried out first so that relaxation of the transferred tendon by wrist flexion may be obtained The rest of the reconstructive program is undertaken after the wrist fusion Various methods of extensor transfer are available (Stiles and Forrester Brown Bunnell Foerster Luckey and McPherson Phalen and Miller)

Luckey and McPherson suggest the following combination The tendon of the musculus brachioradialis is transferred to the flexor pollicis longus the tendon of the extensor carpi radialis longus is severed close to its insertion freed well up into the forearm rerouted subcutaneously on the volar aspect of the wrist, and inserted into the flexor digitorum profundus tendon of the index finger the extensor carpi radialis brevis is rerouted in a similar way and inserted through buttonholes into the flexor digitorum profundus of long, ring and little fingers All reroutings are made in similar ways namely severance of tendons from their inserting points (through a small transverse incision) withdrawal of the tendons higher up in the forearm (through small transverse incisions) and rerouting and reinsertion of the tendon (through a transverse incision in the wrist) To restore opposition of the thumb the extensor carpi ulnaris is rerouted and either inserted to the extensor pollicis brevis or lengthened by a free graft as described on p 755 and 757 As already mentioned the opponens transfer is the first stage of the reconstructive program fusion of the wrist the second stage and the rest of the transfers the third stage

The transplants should be under proper tension According to Luckey and McPherson the tension should permit the proximal two joints to extend to about 140 to 150 degrees at the time of transplantation and

elbow to the metacarpophalangeal joints, is applied The position of the wrist is checked carefully at this time

Dysfunction after Irreparable Paralysis of Nervus Radialis

The deformity following palsy of the radial nerve is typical The nervus radialis supplies the extensors of the hand and fingers Hence, palsy of this nerve causes the hand, if the forearm is held horizontally, to drop The extensor tendons are maximally stretched in this position, and cannot be stretched (relaxed) further if an attempt is made to close the hand to a fist This prevents the flexors from fully functioning If, how-

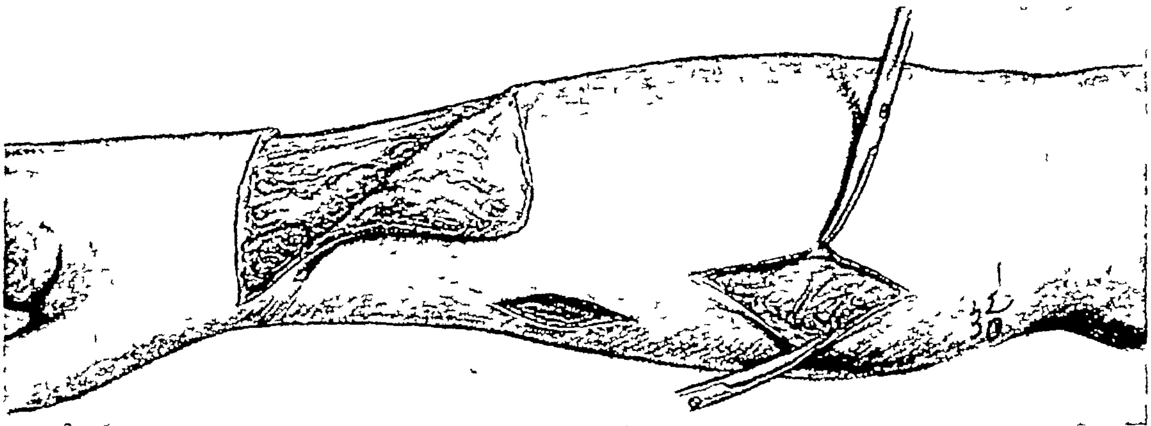


Fig 399 Tendon transfer in paralysis of nervus radialis (Billington) An L-shaped incision is made over dorsum of wrist Dissection of triangular skin flap Two incisions are made on radial side proximal incision, for exposure of pronator teres tendon, distal incision, for exposure of flexor carpi radialis

ever, the hand is held in dorsal flexion (cocked up) in the wrist, the flexors regain their full range of function Hence, the object of reconstruction should be twofold (1) restoration of dorsal flexion of the wrist, (2) restoration of extension of the fingers

Dorsal flexion of the wrist can be achieved in various ways Steindler and Abbott fixed the wrist in position of extension by arthrodesis, Perthes by tenodesis Either method produces a permanent cocked-up position, which complicates the operation and is not felt to be an advantage by the patient However, it may be indicated in paralysis of long duration with secondary contracture of the wrist In the majority of cases, transfer of tendons without tenodesis is sufficient to stabilize the wrist well, furthermore, it permits flexion in the wrist, and the operation is less complicated Consequently, tendon transfer is preferable

Robert Jones's principles of tendon transfer are still widely used today, consisting in transfer of the flexor carpi ulnaris tendon to the extensor communis tendons of the fingers, of the pronator teres to the

wrist After retraction of the skin and subcutaneous tissue the dorsal carpal ligament is incised. The extensor tendons are then retracted and the dorsal aspect of the wrist is exposed The capsule is incised and the navicular lunate and multangular bones are completely removed. Sometimes, it may be difficult to identify the bone area without undue dissection In these cases the removal of a thin layer of bone and periosteum from the dorsal aspect of the radius and the carpal bones in one piece with a broad thin osteotome is advised Following this the various carpal bones are easily identified. A thin layer of bone and periosteum may be replaced at the end of the operation Next, the articular surfaces of the radius capitate and hamate bones are removed with a chisel and gouge until a surface of cancellous bone can be seen A small shallow depression is now gouged into the distal surface of the radius to accommodate the head of the capitate. The radial side of the incision is retracted and the lateral aspect of the radial styloid is exposed 1 5 cm (5/8 inch) from its tip A drill is run through the styloid into the depression made for the head of the capitate followed by the insertion of a stainless-steel or vitallium screw 3 to 3 8 cm (1¼ to 1½ inches) long When the tip of the screw appears on the bottom of the depression in the end of the radius the head of the capitate is forced into the depression The screw can then be driven into the capitate without prior drilling of the bone One precaution should be observed The screw should not be placed too far on the palmar side but must be sufficiently angulated dorsally to obtain a good bite on the capitate While the screw should be long enough to hold firmly in the capitate it must not cross the carpometacarpal joint After firm fixation and proper position have been accomplished chips of cancellous bone taken from the removed proximal row are now placed about the fusion site to round out the bony mass and to reinforce the fusion Care should be taken not to extend the bony mass on the dorsum where it might interfere with the function of the extensor tendons.

After Treatment After closure of the wound a plaster-of paris cast is applied extending from the upper arm to the tips of the fingers and the thumb with the elbow held at a right angle and the forearm to midprone position The wrist is fixed in dorsal angulation of from 20 to 30 degrees or such that the opposed thumb is in line with the forearm To this about 20 degrees of deviation of the wrist toward the ulnar side is added This combination approximates the normal clenched fist position in which the grip is strongest. The cast is carefully molded and cut over the back of the wrist and forearm to allow for swelling At the end of three weeks a second short plaster cast extending from just below the

extensor carpi radialis longus and brevis, and of the flexor carpi radialis to the extensors and abductors of the thumb A similar method was advocated by McMurray, Stoffel, and by Billington in this country (Figs 399, 400) Starr (1922) was the first to suggest leaving one wrist flexor in its original place In a careful analysis of a large series of tendon transplantations performed for radial palsy during World War II in England, Zachary brought this very important point out again, and Scuderi, and Young and Lowe, in this country, concur A transplanted muscle, like any other, has only a limited range of action, if, owing to absence of an antagonist on the flexor side of the wrist, the length of contraction of the fibers is used up in extending the wrist, there will be little left to extend the digits Scuderi, after analysis of his large series of World War II cases, brought another important point out, namely, that the flexor carpi ulnaris muscle is capable of extending the wrist and all the fingers, if properly sutured under the correct amount of tension The author concurs Scuderi also stresses that transplantation of a single tendon into the extensor pollicis longus is far more efficient than transplantation of a single tendon into the extensor and abductor of the thumb or thumb and index finger He therefore makes five points (1) The palmaris longus tendon is transplanted into the severed extensor pollicis longus tendon (2) The flexor carpi ulnaris is transferred into the extensor tendons of the second, third, fourth, and fifth fingers, the flexor carpi ulnaris must be sutured at a 45-degree angle to the long axis of the extensor tendons so that the anastomosis to the extensor tendon of the second finger is about 2 cm (3/4 inch) distal to the anastomosis to the extensor tendon of the fifth finger (3) The action of the flexor carpi radialis into one of the thumb tendons is advocated only if the palmaris longus tendon is absent (4) The transplanted tendon must exert its pull in as straight a line as possible from the origin of the muscle to the insertion of the recipient tendons (5) Preoperative physical therapy must be carried out until complete range of motion is possible in the interphalangeal and metacarpophalangeal joints of the finger

Technic (Scuderi) (Fig 401) (Case 157, p 1062) Before the operation, a volar splint of sheet metal (aluminum) should be prepared to hold the wrist in full hyperextension, the fingers in extension, and the thumb in full abduction The splint is sterilized, and may be applied during the operation, thus replacing an assistant

With the wrist held in extension, the insertions of the palmaris longus and flexor carpi ulnaris are easily identified Short longitudinal incisions are made over the insertion points, and the isolated tendons are cut free When the cut tendon is pulled gently, its proximal portion can be pal-

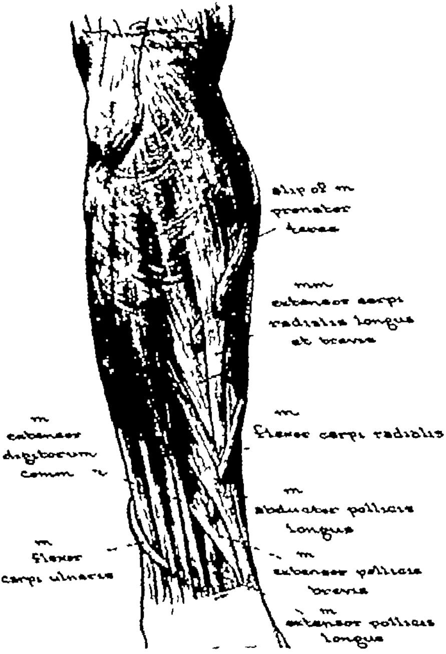


Fig 400 Rerouted flexor carpi ulnaris tendon is drawn through buttonholes in extensor digiti quinti and extensor digitorum tendons and fastened to them. Rerouted pronator radii teres tendon is inserted into tendon of extensor carpi radialis longus and brevis. Rerouted tendon of flexor carpi radialis is drawn through buttonholes of abductor pollicis longus and extensor pollicis brevis tendons and sutured end-to-end to severed extensor pollicis longus tendon.

the tendon The dorsal carpal ligament is severed over the tendon, the tendon is severed as far proximally as possible With a Kelly forceps, a tunnel is now made between the incision in the "snuffbox" and the proximal incision of the palmaris longus The tunnel must be in a straight line with the palmaris longus tendon and the extended and abducted thumb, and must come to lie between the subcutaneous fat tissue and the fascia of the forearm The palmaris longus tendon is withdrawn through this tunnel

A transverse incision is now made over the dorsum of the wrist, and the common extensor tendons of the fingers are exposed The ligamentum carpi dorsale is excised over the tendons (Absence of this ligament does not cause a functional handicap!) A straight tunnel is now made to connect the wrist incision with the proximal incision of the flexor carpi ulnaris tendon The latter is then withdrawn through the wrist incision All wounds on the flexor side of the forearm are closed

The palmaris longus is now anastomosed with the extensor pollicis longus tendon, the thumb being held in extension and abduction, and in a straight line with the palmaris tendon For tendon attachment, the buttonhole technic or a similar one is used The wound is closed

The flexor carpi ulnaris tendon is now anastomosed with the common extensor tendons of the fingers The latter and the wrist are held in extension (seldom will a radial transplant be too tight!) The anastomosis is oblique, the tendon suture to the little finger being 1 5 cm (5/8 inch) proximal to the suture to the tendon of the index finger The recipient tendons are buttonholed at the desired level The transferred flexor carpi ulnaris tendon is slit longitudinally, and half is drawn through the recipient tendons with a Kelly forceps Two interrupted silk sutures are used to fix each tendon The other half of the tendon is laid over the recipient tendons and held in place with only two silk sutures at the proximal and distal ends of the anastomosis The wound is closed in layers, first, the subcutaneous fat tissue, then the skin edges

After-Treatment The previously prepared aluminum splint is firmly bandaged in place If such a splint is not available, a volar plaster-cast splint is applied, reaching from the tips of the fingers, with the fingers slightly flexed in the proximal interphalangeal joints, to the elbowjoint Immobilization is removed after three weeks and physical therapy begun

If the palmaris longus is absent, the flexor carpi radialis is rerouted subcutaneously and anastomosed with the extensor pollicis longus, followed by transfer of the flexor carpi ulnaris to the common extensors of the fingers In this case, the wrist is deprived of both flexors This has certain disadvantages, as mentioned previously To stabilize the wrist,

pated in the forearm 15 to 17 cm (6 to 8 inches) proximally and then through individual short longitudinal incisions each tendon is exposed The tendon of the palmaris longus is withdrawn through the proximal incision The flexor carpi ulnaris has a very low attachment of muscle fibers, which usually reach far down toward the insertion of the tendon They should be sheared off from the tendon up to a point 7.5 cm (3

Fig. 401 Tendon transfer in irreparable radial palsy after Scuderi Transfer of palmaris tendon to extensor pollicis longus and transfer of flexor carpi ulnaris tendon to extensors of second to fifth fingers. Insert shows alternate way of tendon attachment of palmaris tendon and thumb extensor by "buttonhole" technic.

inches) above the wrist to permit better suturing to the recipient tendons and to provide for better gliding This tendon is then withdrawn through the proximal incision

The forearm is now pronated. In the anatomical snuffbox the extensor pollicis longus is located from a longitudinal incision radial to

Amputation seems to be the only solution, particularly if bone is involved There is only one exception If, in a rare case, only one side of the finger is involved and the artery on this side can be ligated, the other artery may be sufficient to keep the finger alive Injection of the superficial veins with sclerosing solutions may be given a trial before amputation is considered, although one must be aware that this may produce necrosis of functioning parts One other method, which has been suggested recently, is compression by rubber bandages Pressure of the superficial veins makes it more difficult for the blood to flow from the artery into the vein, and thus encourages the blood to pursue a normal course

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it may then be of advantage to transplant one or two sublimis tendons into the wrist as suggested by Bickel (after Luckey and McPherson)

If the flexor carpi ulnaris is not sufficient to extend wrist and fingers the pronator teres may be transplanted subsequently into the extensor carpi radialis longus and brevis (after Jones and Billington) (see Fig 400) Saikku advises separating the pronator completely from its whole insertion

Arthrodesis of the wrist in extension should be the last resort It should be reserved for those patients with longstanding secondary contractures of the wrist. (For technic, see p 762)

Vessels

Reparative surgery of the vessels of the hand is essentially the same as described previously (Chapter XXIV p 597) A few points however may be emphasized Suture of a torn vessel will hardly ever be required since the hand has abundant vascular anastomoses and therefore a good collateral circulation Ligation of the injured vessel is the method of choice

The lesions that require reparative surgery are arterial aneurysm and arteriovenous fistula the former is of traumatic origin the latter quite often congenital The symptoms do not differ from those of aneurysms in other parts of the extremities (see p 608) The congenital type results from failure of differentiation of the common embryonic anlage into artery and vein (Reid and others) An extensive review of the subject was presented by Seeger Horton Allen Barker Hines and Curtis In Horton s series of 34 cases 17 involved the arm and hands In some patients, signs and symptoms were present at birth in others were noted much later The involved extremity is usually larger in circumference and length than the other side and the superficial veins are dilated There is increase of heat from arterialization of the venous blood and blood removed from a superficial vein proximal to the fistula shows the bright red color of arterial blood (compare with the blood of a similar vein of the other extremity) and greater oxygen saturation Arteriography can be of great help in establishing the diagnosis and the site of the lesion but as Allen Barker and Hines point out interpretation of the arteriogram may be difficult when small vessels are involved or the fistulas are small From 20 to 30 cc. of contrast material (Diodrast) is injected under local anesthesia into the brachial artery just above the lacertus fibrosus.

Treatment It is unfortunate that in cases of arteriovenous fistulas of the hand or of the finger the arteriovenous communications are numerous Hence in the majority of cases it is impossible to save the finger

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XXX

THE BONES AND ARTICULATIONS

The Bones

DEFECTS (TRAUMATIC)

CONCERNING the traumatic defects amenable to treatment, there are nonunion of the os naviculare (scaphoid bone) and nonunion of the metacarpal bones and phalanges (For replacement of an entire metacarpal bone or phalanx, see p 780) (For congenital defects, see p 819)

NONUNION OF OS NAVICULARE

A fairly large percentage of fractures of the carpal scaphoid bone result in nonunion. The cause is mainly an anatomical one In fractures of other bones—with few exceptions—the periosteum plays an important role in the formation of callus Most of the surface of the scaphoid, however, consists of articular cartilage, leaving little room for active osteogenetic periosteum Hence, its viability and regenerative power depend entirely upon its intramedullary circulation From clinical and experimental experiences (Watson-Jones, Obletz, and Halbstein), it is known that in about one third of the cases most of these vessels enter the bone on the distal (lateral) aspect of the bone and in the constricted midportion, leaving the proximal (median) half supplied by the branches of the main vessels so that this part is rather poorly vascularized (Speed) (see also Bibliography under May) If, in such a case, a fracture occurs *within the proximal half of the scaphoid or through the waist of the bone* where the center vessels enter, rupturing their trunks, the proximal half of the scaphoid is cut off from its circulation and dies (Fig 402) In this respect, it resembles the central fragment of the neck of the femur in a true intracapsular fracture (see p 638) The only way in which the necrotic

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culus extensor pollicis longus is retracted ulnad (see Fig 336) The periosteum over the styloid process is then incised in the long axis, together with the capsule of the wrist joint, which at this point is largely the radial collateral ligament The process is then freed subperiosteally of all soft tissue and removed with an oblique osteotome The starting point should be 1 5 cm (5/8 inch) up the radial shaft in order to obtain a sufficiently large fragment to be reshaped Upon removal of the process, the navicular bone will be found to lie directly in the wound, in most instances, the fracture will be visible The tuberosity of the navicular can then be exposed easily with avoidance of its dorsal arterial supply After the most prominent areas of the tuberosity have been cleared, a small nick is made *in the bone at this point with rongeurs, in order to provide for countersinking of the graft and prevention of bone proliferation, which might interfere with abduction of the wrist With a small drill (5/16 inch)*, a hole is drilled beginning at the neck of the tuberosity, through the proximal fragments, across the fracture line, and into the distal fragment, care being taken not to perforate the semilunar facet of the scaphoid A picture by portable x-ray equipment is now taken to evaluate the position of the drill If the position is correct, a bone peg is shaped from the removed styloid process or the subcutaneous border of ulna or tibia It is then driven into the drill canal Again, an x-ray picture of the scaphoid should be taken to evaluate the position of the graft If the graft is found in correct position, bridging both fragments, only then should the projection of the graft be cut at the entrance of the drill canal If this had been done before the x-ray examination, one would have been deprived of the possibility of removing the graft for correcting its position if such were warranted The radial collateral ligament is sutured over the raw surface of the radius and the wound closed in layers

After-Treatment The hand is supported in a circular plaster cast in cockup position, with the thumb in abduction, for eight weeks After removal of the cast, an x-ray picture is taken for evidence of union of the fragments If it is satisfactory, physical therapy is instituted Should union be delayed, immobilization of the wrist for another four weeks is advisable

Nonunion of Metacarpal Bones and Phalanges

Nonunion of these bones may cause pain and dysfunction, particularly if the fragments are displaced Bridging the defect with a bone graft offers a good chance for establishing bony union (Murray)

Technic. *Nonunion of Metacarpal Near Head of Bone* The bone is exposed from a dorsal incision The extensor tendons are mobilized and retracted The distal head fragment is usually displaced toward the palm, it is mobilized and, after removal of all scar tissue between the fragments,

fragment can become regenerated is by ingrowth of vessels and osteoblasts from the live part. To assure this, absolute prolonged immobilization must be carried out until the x ray picture reveals complete regeneration If nonunion should develop and the median fragment remains necrotic, excision of the fragment may be considered (Waugh and Reuling have suggested the entire replacement of the os naviculare by a vitallium replica.) If however the x ray picture reveals nonunion and both fragments are alive (after a fracture through line *a* for example) a

Fig. 402 Carpal scaphoid bone. Representation of its vessels (compare with Fig. 31) and relation between fracture lines and these vessels (Böhler and Schneck) In fracture through *a* both fragments remain alive while fracture through *b* and *c* will cause necrosis of median (proximal) fragment.

bone pegging operation has a good chance of uniting the fragments. The author has preferred a tibial bone peg as a graft (Case 158 p 1063) Barnard and Stubbins point out that the removal of the radial styloid process does not interfere with a normally functioning wrist joint and its removal simplifies the surgical approach the removed bone can be used as a graft A recent presentation by Stubbins of a long-term follow up examination of his patients, all successfully healed after this technic, is impressive

Technic (Case 158 p 1063) After the application of a pneumatic tourniquet (see p 716) a curved incision is made on the radial surface of the wrist joint extending about 3 2 cm (1¼ inches) upward and downward from the radial styloid The incision is curved towards the volar surface of the wrist and the convexity should reach the tendon of the musculus abductor pollicis longus The superficial radial nerve should be exposed and then retracted ulnarward The deep fascia and the dorsal carpal ligament are divided longitudinally exposing the extensor pollicis brevis and abductor pollicis longus tendons These tendons are retracted toward the volar side together with the radial artery while the tendon of the mus

Compression of the graft between the two fragments is sufficient to hold it in place at the base Should additional fixation be required, it can be obtained by the use of Kirschner wires drilled either longitudinally from the carpal bones into the graft or transversely to transfix the graft between two normal metacarpal bones (Cases 159, 160, p. 1064, 1066) The wounds are then carefully sutured

Defects of Several Metacarpal Bones (after Bruner)· If the shafts of several metacarpal bones are missing, a full-thickness iliac bone graft (see p 63) is interposed en bloc and held transfixed with Kirschner wires A tendon defect, which may exist simultaneously, should be bridged later, after the bone graft has healed

Nonunion of Phalanges The bone is exposed from a lateral incision and the bone graft inserted in a manner similar to that described for nonunion of the metacarpal bone near the head of the bone

After-Treatment A plaster cast is applied in the position of function About twelve days later, the cast is changed, sutures are removed, and a new cast is applied, immobilizing the wrist and the proximal phalanx of the grafted metacarpal This cast remains for about two months

DEFORMITIES (TRAUMATIC)

Traumatic deformities of the metacarpal bones or the phalanges are the result of malunion after fractures The deformity rarely causes dysfunction of such degree as to handicap the patient. Open reduction, after osteotomy of the bone, however, is indicated in some cases Internal fixation by bone-grafting (see Nonunion of Metacarpal Bones, p 777) or wiring may be necessary, in addition to external immobilization. A good method of fixation is by drilling Kirschner wires through the affected and neighboring metacarpal bones (Snedecor) (compare with Cases 159, 160, pp 1064, 1066) (For congenital deformities, see p 819)

The Articulations

ARTHRODESIS

Arthrodesis of the digital joints is a helpful procedure for stabilization of the joint in certain irreparable nerve lesions or contractures, and for correction of position in joints fused in malposition, rarely for relief of arthritic lesions The joints to be arthrodesed are the metacarpophalangeal joints, less often is there an indication for fusing the interphalangeal joints

Technic (See Fig 398) From a dorsal tendon-splitting incision, the joint capsule is incised longitudinally The articular surfaces are re-

the latter are brought into alignment. A thin cortical bone graft is removed from the subcutaneous border of ulna or tibia and driven into the proximal fragment. A hole is now drilled into the distal fragment and the latter fitted over the distal part of the bone peg

If the fragments cannot be separated and retracted sufficiently to fit the distal fragment over the bone peg the author recommends the following procedure The bone graft (peg) is fitted first into the distal (head) fragment. A graft bed is prepared in the proximal fragment by removing the dorsal part of the cortex until the medullary cavity is exposed. The proximal portion of the bone graft is laid upon the proximal fragment and held in place with two thin wires slung around the bone

Nonunion of Shaft of Metacarpal Bone (after Armstrong) From a dorsal incision the extensor tendons are retracted and the affected metacarpal bone exposed by a longitudinal incision through its periosteum The bone ends are exposed subperiosteally and cleared of fibrous tissue, and the fracture is reduced With a double saw adjusted so that the outer surface of the blades are 0 5 cm (3/16 inch) apart, a graft bed about 3 8 cm (1½ inches) long is cut on the dorsal aspect of the bone A cortical graft is removed from the tibia with a double saw adjusted so that the inner surface of the blades are just over 0 5 cm (3/16 inch) apart. This graft is inserted into the graft bed and should fit very closely It is driven in with a punch until its cortical surface is flush with the cortex of the host bone If the graft fits closely no other fixation is necessary Otherwise, Kirschner wires are drilled through the affected and neighboring metacarpal bones (see the following discussion)

Defects of Shaft of Metacarpal Bones (after Littler) In any of these cases the overlying skin may be cicatricial and may need replacement If later tendon work is planned it will be necessary for the skin to be replaced by a well padded abdominal flap (compare with Case 160 p 1066) The metacarpal defect is exposed from a longitudinal incision All fibrous tissue between the fragments must be removed radically In most cases the proximal fragment must be sacrificed as far as the base where it is resected with an osteotome with an angle of approximately 30 degrees With traction on the finger the defect between the metacarpal fragments is measured and a graft, measuring at least 1 3 cm (½ inch) longer than the estimated defect is taken from the upper end of the tibia A dowel is fastened at one end of the graft and with a circular saw the other end is cut obliquely at an angle of 30 degrees The dowel end of the graft is inserted into the medullary end of the cavity at the distal fragment at the proximal end the graft is pressed into the metacarpal or carpal recess.

TRANSPLANTATION OF JOINTS

Indications for joint transplantation have been outlined previously (p 673) In general, the procedure consists in replacement of half a joint together with part of the bone In short medullated bones, such as the metacarpal bones and digital phalanges, it is possible to replace the entire bone, together with its joint surfaces

Removal of these bones may be indicated in badly comminuted fractures, or for benign tumors (enchondroma), low-grade malign tumors, or those malign tumors which are still confined to the bone itself Replacement is indicated in order to preserve the finger and its motility

In traumatic cases, preliminary operations may be necessary Any missing skin must be replaced with a well-padded flap prior to the transplantation, all destroyed tissue—this includes bone also—and all scar tissue must be removed The missing metacarpal cannot be replaced during the flap transfer This, however, would inevitably cause the digital phalanges to retract into the defect To prevent this, the first phalanx must be suspended temporarily with the aid of a Kirschner wire drilled horizontally through the neighboring phalanges, the wire coming to lie just beneath the digital webs At the entrance the wire is cut, and the small entrance incision is closed (see Case 160, p 1066) After all wounds have healed, the metacarpal defect is replaced with a metatarsal graft Graham and Rioidan use the fourth and fifth metatarsals as a graft, since they are functionally less important than the others they prefer the fifth because it has caused less impairment to the foot than removal of any other one The author agrees with this from his own experience

Technic (Case 160, p 1066) From a dorsal longitudinal or other suitable incision, the bone is exposed by holding the extensor tendon laterally The diseased or damaged metacarpal should be removed, leaving the base and as much of the shaft as possible The entire joint capsule should be removed The shaft of the metacarpal is cut in such a manner that a close approximation with the transplanted metatarsal will be possible The metatarsal bone, preferably the fifth, is removed with a Gigli saw Care should be taken that the periosteum remains intact The bone graft is then inserted into the defect and held in place with a Kirschner wire, which is drilled from the proximal portion of the metacarpal bone through the center of the transplanted metatarsal Another Kirschner wire is then inserted through the proximal heads of the neighboring metacarpals and the head of the transplanted metatarsal Graham and Riordan advise fixing the extensor tendon fully to the proximal end of the proximal phalanx to prevent anterior subluxation of the phalanx The exposed bone surface should be covered with fat tissue or soft tissue

moved with a gauged chisel With a V shaped chisel a groove is carved on the dorsal surfaces of the bones for reception of the bone onlay graft. The latter is removed from the lateral surface of the ulna of the same arm or from the anterior edge of the tibia. The joint is flexed in the position of function i e semiflexion in the metacarpophalangeal joints of the second to fifth fingers while the metacarpophalangeal joint of the thumb is flexed so that the tip of the thumb and the other fingers can be apposed A short Kirschner wire is drilled through the bones across the joint surfaces well anterior to the graft bed The bone graft is now placed into the previously prepared graft bed The capsule is closed over the graft and this is followed by suture of the split extensor tendon and the skin A dorsal molded plaster-cast splint is applied from the forearm to the arthrodesed finger with the wrist in cocked up position

After Treatment The cast is temporarily removed on the tenth day for removal of the sutures It is then reapplied for at least eight weeks until there is roentgenological and clinical evidence of sufficient fusion

ARTHROPLASTY

Arthroplasty of an ankylosed finger joint is rarely performed because the operation is not often successful ankylosis is apt to recur since the tendons owing to long inactivity have contracted and instability is difficult to control In some selected cases however the operation may be warranted It is indicated only for the metacarpophalangeal joint, except for that of the thumb The surrounding skin must be in good condition and the *muscles and tendons must be functioning well*

Technic (Campbell) The ankylosed joint is exposed through a 5-cm (2 inch) longitudinal incision on the dorsal surface of the joint The extensor tendon is either held laterally or split longitudinally and retracted The joint region is exposed The ankylosis of the joint is broken up with a small-gauge chisel and the ends of the bone remodeled the head of the proximal part being smoothed to present a rounded convex surface which conforms to a concavity created in the articular surface of the base of the distal part. A thin strip of fascia lata of appropriate size is removed from the thigh folded over the proximal head and held by a pursestring suture. The remaining portion of fascia is reflected over the distal joint surface and stitched in place to form a double lining of the articular surfaces. The wound is closed in layers.

After Treatment The finger is placed in semiflexion on a dorsal molded plaster-cast splint. After three weeks the splint is removed and active exercises are instituted followed by passive exercises one week later

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to prevent adhesions of the extensor tendons (see Case 160 p 1066 in which part of the subcutaneous tissue of the flap was used for this purpose) All wounds are then closed.

After Treatment The hand is splinted in full extension for three weeks. Active and passive mobilization is then instituted. After the bone graft has completely healed in place, which is usually the case after about four months, the transverse wire is removed Otherwise it is left in place It may happen that in traumatic cases the intrinsic system is damaged a sublimis transplant may then be necessary to replace the damaged intrinsic muscles as described on p 797 To obtain a stable joint the restoration of intrinsic function is absolutely necessary

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the hand and united with the stump of the finger After it has healed in place, it is severed from its pedicle, and the raw peripheral surface is closed After all edema in the flap has disappeared, the flap is opened along its seam, a bone graft is taken from the crest of the ilium (p 63), or one of the metatarsal bones is used as a graft (see p 780) This graft is either wedged into the base of the remaining phalanx or metacarpal bone or held in apposition by intramedullary Kirschner-wire fixation The flap may need thinning by removal of some of its subcutaneous fat tissue to permit closure around the bone graft

If, with the exception of the thumb, all fingers and parts of their metacarpal bones are missing, the loss is serious, since the thumb is left with no opposing structure and hence no grasping surface To restore a grasping surface, an open abdominal flap is made and its peripheral end sutured to the dorsal defect edge This flap should be sufficiently long to permit folding upon itself after it is severed from its pedicle In other words, the flap will have the shape of a mitten (Case 159, p 1064). After it has healed in place and all edema has subsided, the flap is unfolded by incising the volar scar, a periosteum-covered bone graft is removed from the anterior surface of the tibia or crest of the ilium and shaped to proper size for horizontal placement into the flap, with the medullary side against the freshened bone stumps of the metacarpal bones, it is held in place by internal fixation with Kirschner wires. The flap is then reflected over the graft and sutured in place

After-Treatment The newly formed extremity is encased in a plaster cast, it should remain immobilized until the x-ray picture reveals firm union between graft and host bone

NEOPLASTY OF THUMB

The thumb is our most important finger Its loss may cripple the function of the hand severely If this is the case, a reconstruction of the thumb becomes advisable From anatomical considerations, the thumb is the shortest of all fingers It barely reaches the first interphalangeal joint of the index finger The latter is not the longest finger, but has the longest metacarpal bone The first metacarpal bone is the insertion point of numerous functionally important muscles, of which the abductor and the opponens muscle are the most important The abductor inserts at the base of the first metacarpal bone, although the opponens muscle inserts along the entire radial surface of the bone, a metacarpal stump from 1 to 1 5 cm ($3/8$ to $5/8$ inch) long is still sufficient for satisfactory muscle action of the opponens Hence, it would be a serious mistake to

XXXI

THE HAND AND FINGERS IN TOTO

Neoplasty of Fingers

THE handicap following loss of fingers is severe that from the loss of the thumb is even more so There are various methods of repair Each one—however ingenious—may result in failure a possibility to be recognized by surgeon and patient before the operation Neoplasty of the fingers has undergone many changes since World War II Some of the older methods were found unsatisfactory and given up others proved satisfactory but needed improvement The replacement of digital phalanges by composite flaps was found to have only limited use The replacement of the thumb by another finger has stood the test of time in principle but the method has been much modified and improved In certain cases phalangization (using the metacarpal bones for restoring function when phalanges are missing) is still a useful device Rotation osteotomies and the interchange of fingers have definite usefulness in limited fields

REPLACEMENT OF PHALANGES BY COMPOSITE FLAPS

Various methods have been devised (Schepelmann Albee Kallio Creeley) employing the principle of transplanting a flap from the abdomen containing a bone graft. The bone graft is incorporated into the flap either before or after the latter is transferred to the finger Regardless of the source of the graft the danger of its absorption is always present and the flap lacks tactile sensation Consequently this method should be used only if other better methods (see below) are not available.

Technic (Case 159 p 1061) A tube flap or open pedicle flap of suitable size and length is made at the abdomen The flap is then transferred to

Replacement of Thumb by Another Finger

Before thumb reconstruction can be considered, any significant scar over the stump or in the web should be revised and if necessary corrected by an abdominal flap The most effective thumb-replacing method is the substitution by another finger The principle of the operation was conceived by Lucksch, and the method was subsequently modified in various ways by Hulsmann, Portzelt, Buzzelo, Perthes, Bunnell, Iselin, Tanzer, Littler, Graham, Hilgenfeldt, Gosset, and others The various methods may be divided into those in which the entire (index) finger, including its metacarpal, is used to replace a total thumb and into those in which only a portion of the (index or third) finger is used to lengthen a partly amputated thumb The technical problems are somewhat different In the latter method, the pedicle of the transferred finger consists only of a neurovascular bundle or of a thin, narrow skin bridge containing the neurovascular bundle In the former method, the pedicle is much broader To Perthes, Bunnell, and Iselin goes the credit for having developed the broad-pedicle method It was Bunnell who, in 1928, succeeded in replacing a thumb by an index finger, which had both motion and nerve supply The neurovascular-pedicle method, the original method of Lucksch, has been independently developed and improved upon, both during and after World War II in different countries (Hilgenfeldt, Bunnell, Littler, Gosset)

Hilgenfeldt had the great opportunity of treating a large series of German wounded soldiers in whom the thumb was missing He used the neurovascular-pedicle method, and published his methods and results in a monograph Some historical notes are of interest

Lucksch, in 1903, presented a patient in whom he had replaced the missing phalanges of the thumb with the phalanges of the neighboring index finger Lucksch had severed the dorsal skin and extensor tendons over the first phalanx of the index finger, then severed the first phalanx itself and the flexor tendons, he left a volar bridge of skin, containing the volar digital arteries and nerves, intact The finger hanging on this narrow skin flap was transferred to the stump of the thumb, and the bones were fastened with silver wires After twelve days, he severed one half of the skin bridge, and the second half after three weeks Lucksch was the first to demonstrate that a narrow strip of skin containing only the volar digital arteries provided sufficient circulation for the finger By severing the volar pedicle, however, he deprived the finger of its sensitivity

Hilgenfeldt's contribution is that, while he followed Lucksch's method, he incorporated the skin-vessel-nerve pedicle permanently, thus

sacrifice even the smallest metacarpal stump primarily or secondarily Aside from sacrificing important muscle function the replacement at the carpometacarpal joint would be difficult. This joint formed by the greater multangular and first metacarpal bone is a saddle joint permitting abduction and adduction and also rotation of the thumb

If a thumb is absent the choice of reconstruction depends upon the level of the amputation Partial amputation distal to the metacarpophalangeal joint generally requires nothing more than the formation of a nontender stable tip In amputations at the metacarpophalangeal joint an operation for phalangization is the method of choice (see p 797) Amputation through the metacarpal requires a replacement operation The new thumb—aside from other requirements to be mentioned later—should have normal sensitivity Numb fingers are considered a serious handicap by patients. Hence, reconstruction of the thumb with composite flaps from distal parts of the body (Case 159 p 1064) should be considered a last resort, since the replaced skin never regains normal sensitivity The most valuable procedure is replacement of the thumb by another finger In replacing the thumb by another finger there are certain requirements The volar digital arteries and nerves of the replacing finger should be intact. The dorsal vessels and nerves are not important since both volar structures are sufficient to supply the dorsal side with ample circulation and sensitivity Tactile and thermal sensitivity alone, however is apparently not enough to give the patient the feeling of having a new thumb he seems to localize the sensorial conception of touch in the replacing finger at its former site. Something else seems to be required as reported by Hilgenfeldt in an interesting case A patient in whom the third finger replaced the missing thumb sensed the new thumb as a thumb only after the flexor tendon of the former thumb was attached to the flexor tendons of the transferred third finger

Conclusion The finger replacing the thumb should have the following qualities It should be long enough to permit a pinch and a broad grasp It may be shorter than a normal thumb It is not necessary that it be mobile in all joints however the carpometacarpal joint must be completely mobile There should be no contracture in the interdigital space The interdigital space should be deep enough and consist of skin with normal sensitivity The two volar digital arteries and nerves of the replacing finger should be present. If another finger is also damaged in the trauma to the thumb the damaged finger should be considered for replacing the thumb

digital webs, and from here, it is led forward toward the palmar incisions In this way, a dorsal skin flap is outlined and dissected free, later, it will be used to cover the head of the third metacarpal bone The extensor tendons are severed as proximally as possible to the metacarpophalangeal joint The finger is now disarticulated at the metacarpophalangeal joint, before the palmar side of the capsule is severed, a grooved director is passed between capsule and flexor tendons to protect the latter The lumbrical

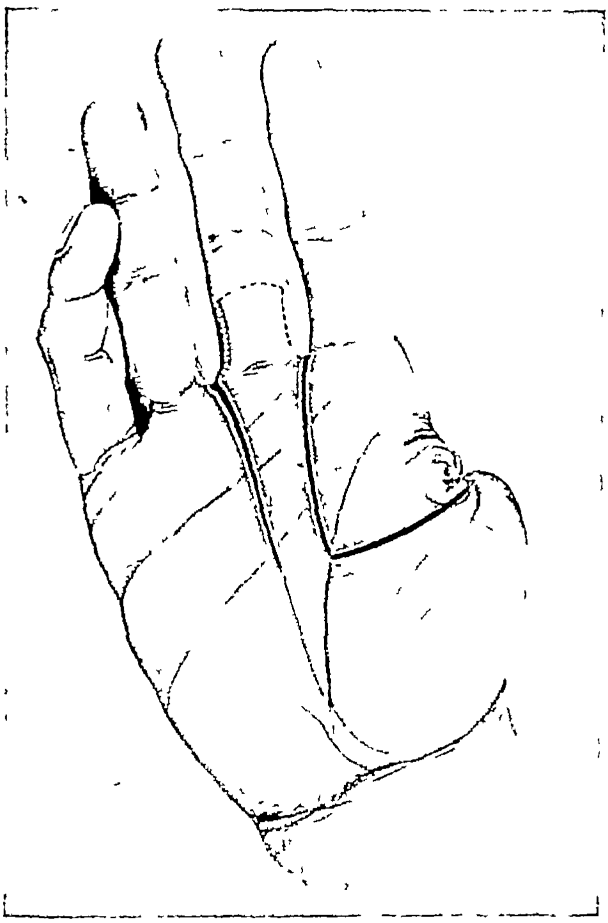


Fig 403 Thumb substitution with third finger, after Lucksch-Hilgenfeldt. Palmar bridge flap containing neurovascular bundle of third finger outlined, also incision to stump of thumb for reception of bridge flap, and dorsal flap of third finger (dotted lines) are outlined (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

and interosseous muscles leading to the third finger are divided next The finger is now hanging on the flexor tendons and the previously formed skin bridge with the volar nerves and arteries (Fig 406) If this bridge is not long enough to permit easy rotation of the finger beyond the first metacarpal, it can be lengthened, and the vertical septa of the palmar fascia may be incised Since the entire third finger would be too long to replace the thumb, one must now determine how much of the first phalanx

preserving sensitivity in the finger Whenever possible he uses the third finger for substitution He argues that the index finger has greater range of abduction and adduction it has greater usefulness and for this reason should be left in situ He severs the dorsal skin vessels nerves and extensor tendons (since these vessels and nerves are less important than the volar ones) disarticulates the metacarpophalangeal joint forms a volar skin bridge containing flexor tendons volar digital arteries and nerves transfers the finger upon the stump of the first metacarpal bone and permanently incorporates the volar bridge flap In the same or a second stage he transfers the long flexor tendon of the thumb to the flexor tendons of the transferred finger and thus—as the experience of his patients showed—changes the sensorial conception of touch in the transferred finger to that of a normal thumb He operates in one stage if the tendon stump of the flexor pollicis longus can be readily located if not a second-stage operation is performed from four to six weeks later to unite the flexor pollicis longus with the flexor profundus of the third finger

Technic (Lucksch Hilgenfeldt) (Figs 403–408) (Case 161 p 1068) With the patient under general anesthesia and with a pneumatic tourniquet applied two parallel incisions are made in the palm from the radial and ulnar sides of the interdigital web of the third finger leading proximally The incisions are not more than 1 cm (3/8 inch) apart and end at the longitudinal crease of the palm (Fig 403) After the skin is incised the subcutaneous fat tissue is severed somewhat beyond the skin edges thus creating a wider base for the rather narrow skin bridge The digital nerves are located by careful dissection Then the bifurcations of the digital arteries are found between the digital nerves The arterial branching occurs just proximal to the webs. The branch leading to the second and fourth fingers is ligated and severed leaving the two branches to the third finger intact Arteries and nerves are dissected free proximal to the skin bridge (Fig 404)

The scar over the stump of the first metacarpal bone is now excised and the bone exposed From here a horizontal incision is led to the base of the skin bridge of the third finger (Figs 403 404) The wound edges are retracted An effort is made to locate the stump of the long flexor tendon of the thumb If it can be found the operation may be finished in one stage otherwise two stages are necessary

The operation is now continued on the dorsal side of the third finger (Fig 405) A horizontal incision is made at the middle of the first phalanx or even more proximally Skin digital vessels and nerves are severed. From each end of the incision a lateral incision is made to the inter

careful hemostasis is performed A longitudinal incision is made over the first metacarpal bone to locate the tendons of the extensor pollicis longus and brevis The two bones are now pressed into each other so that the pollicizing finger (the new thumb) is in 10-degree flexion, the bones are transfixed by an oblique Kirschner wire The extensor tendon of the third finger is split longitudinally, one half is sutured to the ex

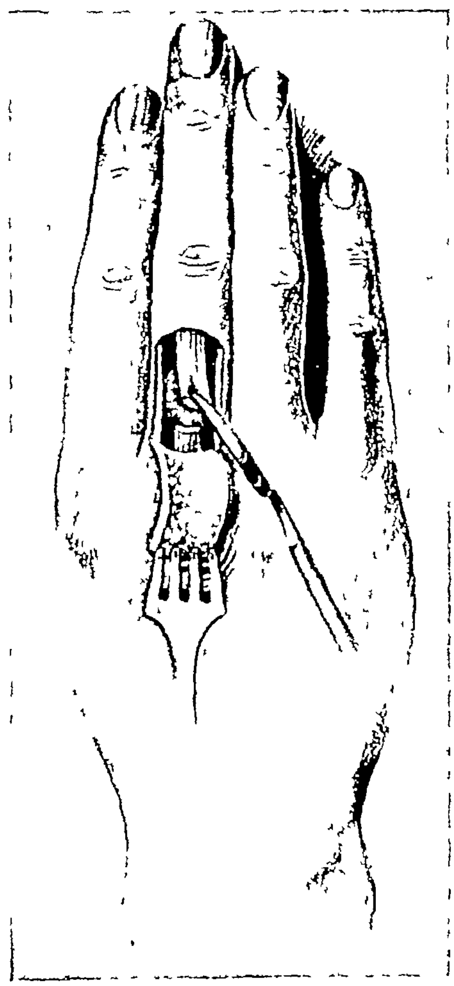


Fig 405 A dorsal flap to cover metacarpal head of third finger later on is reflected, severance of extensor tendon proximal to metacarpophalangeal joint (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

tensor pollicis longus, the other half, to the extensor pollicis brevis (Fig 408) The skin is then sutured on the dorsal side

With reference to the search early in the procedure for the flexor pollicis longus tendon, Hilgenfeldt advises division of the profundus tendon of the third finger and uniting it with the tendon of the flexor pollicis longus As mentioned earlier, if the pollicis longus tendon cannot be found, a second stage is necessary

of the third finger should be removed The stump of the first metacarpal is left as long as possible unless the metacarpal head is preserved in such a case the head part should be removed. The tip of a normal thumb barely extends beyond the middle of the first phalanx of the index finger Hence the first phalanx of the third finger should be shortened accordingly One should however allow for the additional length required by the dovetailing that will hold the two bones together The mobilized third finger is now

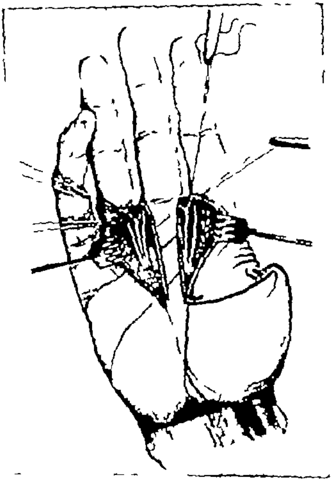


Fig. 406 Ligation of branches of digital vessels leading to second and third finger (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

placed upon the thumb metacarpal and rotated in opposition to the remaining finger and the two bones are prepared for the dovetailing The tongue is made in the first phalanx of the third finger the groove in the first metacarpal bone (Fig 407) The tongue is made by driving a strong knife into the first phalanx of the third finger with a small metal hammer In this way two parallel cuts are outlined and the parts lateral to these cuts are removed with a small rongeur The groove in the metacarpal bone is made similarly The tourniquet is now released and

another two weeks (the author prefers three weeks). (For further readjustment of tendons and the intrinsic system, see Fig 413)

As to the selection of the finger for transfer when the thumb is absent and the remaining four fingers are functioning, Hilgenfeldt, as already stated, prefers the third finger rather than the index finger for substitution He argues that the index finger has greater range of ab- and adduction, thus it has greater usefulness and for this reason should be left behind If, however, the index finger is damaged and the other fingers are intact, the index finger should replace the thumb The fourth finger will rarely be used, and only in cases where the first three fingers and larger parts of their metacarpals are missing When the first, second, and third metacarpal bones are still present, an operation for phalangization (see p 797) is advisable

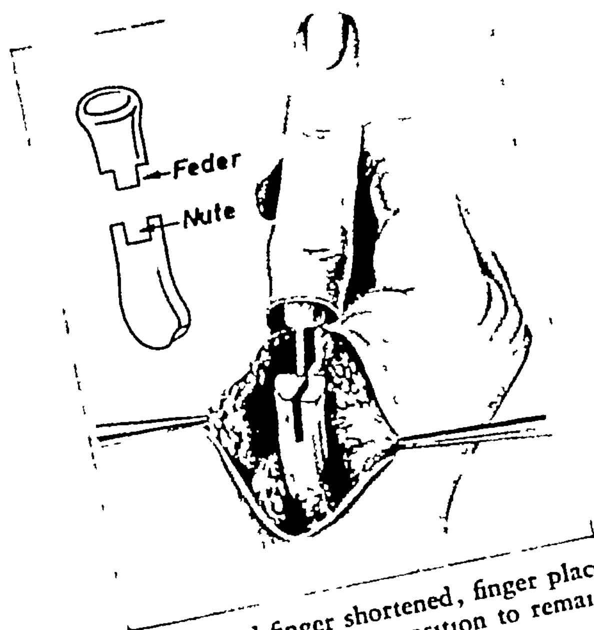


Fig 407 First phalanx of third finger shortened, finger placed upon stump of thumb metacarpal and fastened by dove-tailing in opposition to remaining fingers (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

Bunnell and Littler went one step farther than Lucksch and Hilgenfeldt While the latter kept the pollicizing finger attached to the circulation by a flap consisting of a narrow skin bridge and the neurovascular bundle of the isolated finger, Bunnell and Littler used the neurovascular bundle alone without the skin bridge, hence the method of the vascular-pedicle-"island" flap (p 73) provided the principle of the neurovascular-flap transposition of a digit Littler originally used the index finger for substitution and developed a versatile and reliable method The procedure, however, requires more dissection than Hilgenfeldt's That the fourth, and even the fifth finger, can be transferred without the skin

All wounds are sutured and the finger is immobilized in a dorsal plaster-cast splint reaching from the forearm to the tip of the thumb which is held in abduction and opposition

If the second stage becomes necessary it is performed from four to six weeks after the first stage Hilgenfeldt recommends local anesthesia since it is difficult to locate the flexor tendons of the transplanted third

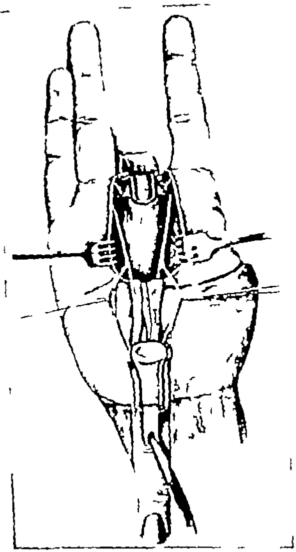


Fig. 406. Disarticulation of finger in metacarpophalangeal joint. Finger hanging on neuro-vascular bundle flap and flexor tendons. (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

finger if the patient is under general anesthesia From a transverse incision over the flexor surface of the wrist one finds the two flexor tendons of the third finger and the flexor pollicis longus The flexor profundus of the third finger and the flexor pollicis longus are divided and sutured together Again a dorsal molded plaster-cast splint is applied for at least

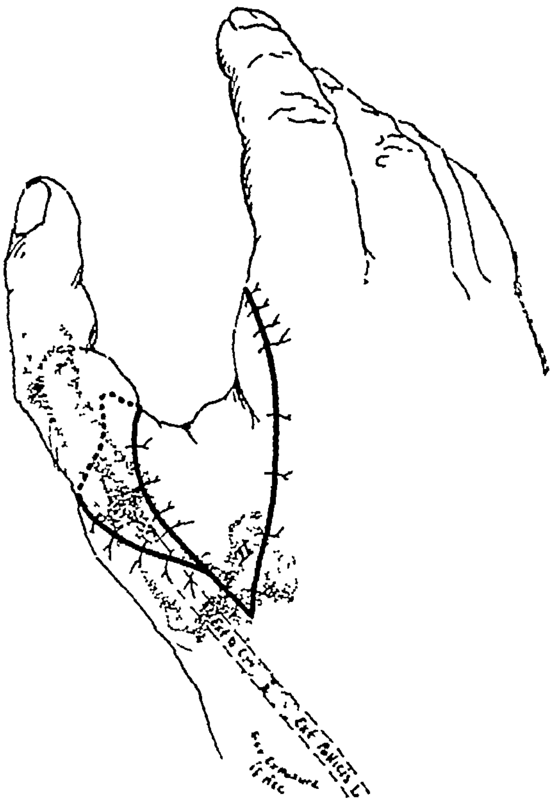


Fig 412 Completed transposition The first metacarpal is firmly joined to the proximal phalanx of the index through an intramedullary bone graft and oblique Kirschner wire at approximately 10 degrees of flexion and pronation This restores a more natural longitudinal arch and better opposition At this stage an end-to-end suture should be made between the extensor pollicis longus and the extensor digitorum communis The flexor pollicis longus can be sutured to the index profundus at a later date (3-4 months) to provide greater strength and independency. (J W Littler Plast. & Reconstruc. Surg)

normal length, the distal portion of the second metacarpal is removed, together with the proximal portion of the first phalanx (compare with Fig 409, *B*) Otherwise, it is preserved (compare with Fig 409, *A*) The thumb metacarpal is now exposed by excision of the underlying scar tissue Its distal portion is cut at an angle of about 20 degrees forward An intramedullary bone graft, which is fashioned from the proximal stump of the second metacarpal, is driven into the first metacarpal, the index finger is now transposed, rotated in pronation about 15 degrees on the thumb metacarpal (i e, in opposition to the tips of the other fingers), and fixed upon the bone graft to the thumb metacarpal, a Kirschner wire is drilled obliquely through the fragments to hold the transposed finger in 10-degree flexion (compare also with Hilgenfeldt's method of transfixion, Fig 407) At this stage, an end-to-end suture should be made between the extensor pollicis longus and the extensor digitorum communis The flexor pollicis longus is sutured to the index profundus at a later date (after three months), the sublimis tendons may also be shortened at that later date to overcome the slack secondary to recession followed

bridge i e attached only on the neurovascular bundle has been recently demonstrated (Kelleher and Sullivan article to be published)

Hence any finger can now be used for substitution of the thumb The most important requirement is that the circulation of the pollicising

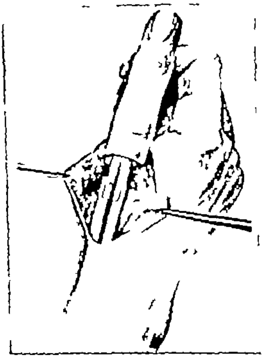


Fig. 408: Extensor tendon of third finger is split one half sutured to extensor pollicis longus tendon, other half to extensor pollicis brevis tendon. (O Hilgenfeldt, Operativer Daumenersatz, F Enke, Stuttgart)

finger is adequate The following test may be helpful a pneumatic tourniquet is applied and inflated in the usual way (p 716) and deflated after several minutes If a finger remains anemic temporarily after the other fingers have regained normal color the circulation in the anemic finger must be considered inadequate If this is the case (Case 161 p 1068) another finger must be used for substitution

Technic (Littler) (Figs 409–418) Skin incisions are made encircling the index finger at the metacarpophalangeal level with the formation of a small triangular dorsal flap attached to this finger Another incision is made to outline a large triangular dorsal flap pedicled in the palm for better exposure and preservation of the web (Fig 409) The small dorsal triangular finger flap is elevated for exposure of the extensor tendons and dorsal aponeurosis the intermetacarpal neck ligament (to be divided) and the common volar artery with its digital branches to the index and third fingers (Fig 410) On the radial side of the index finger the radial neurovascular bundle the lumbrical the first dorsal interosseous and the adductor muscles are exposed Exposure of these structures is facili

pacity of the hand to some degree The method has been improved by various surgeons (Klapp, Perthes, Kallio, Pieri, Iselin, Bunnell, Kreuz, Brown, D'Aubigné, and others) The most recent modification comes from Hilgenfeldt, who made use of his formerly described principle of finger transfer Phalangization is a reliable method It can be used when

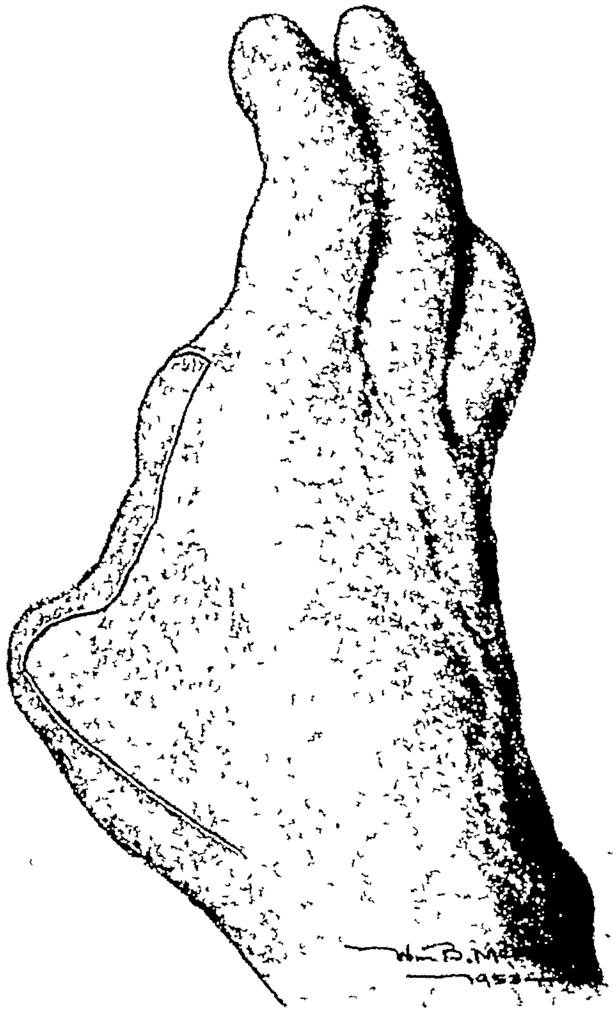


Fig 414 Dorsal incisions for phalangization of first metacarpal bone after Iselin Incision is made over dorsum of first metacarpal bone, it then follows the web between thumb and index finger metacarpal, crosses over to palm and continues along longitudinal crease

the first three or four fingers or even all fingers are absent, but most of the metacarpal bones, particularly the first one, is present It can also be used when the second to fifth fingers are present, but the thumb phalanges are absent, provided the entire thumb metacarpal is present

To create a cleft, it is necessary to remove some of the muscles between the first and the other metacarpal bones, the first dorsal interosseous can be excised completely without subsequent impairment of

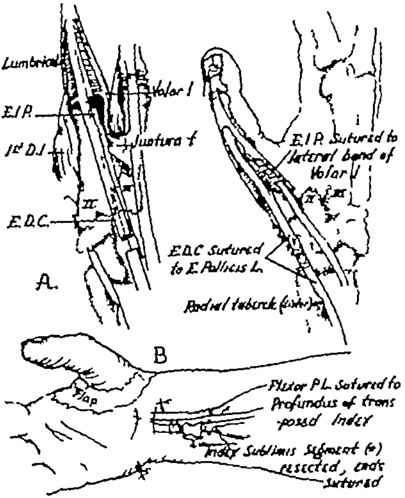


Fig. 413 When an index finger is isolated, recessed, and transposed to thumb position the intrinsic and extrinsic musculature suffer a marked loss of amplitude. A readjustment of tendon length and insertion is therefore important if power and a full range of extension and flexion are to be regained.

A. The important intrinsic interphalangeal extension is retained through a suture of the extensor indicis proprius tendon to that of the volar interosseous (ulnar lateral band of index extensor aponeurosis) The extensor digitorum communis is sutured to the extensor pollicis longus.

B. More independency and flexor power is gained at a second stage by suturing the flexor pollicis longus to the index profundus and by resecting an appropriate segment from the index sublimis tendon. (J W Littler Plast. & Reconstruc. Surg.)

by readjustment of other tendons (Fig 413) The dorsal triangular flap for preservation of the web is laid upon the raw surface and sutured in place followed by adjustment of the small dorsal triangular flap of the transposed index finger (Fig 412)

After Treatment See p 791

Phalangization Replacement of Function of Missing Phalanges of Thumb by Using Metacarpal Bone

The principle of the method first described by Huguier in 1852, is the creation of a cleft between the first metacarpal bone and the remainder of the hand thus restoring the pincer action and grasping ca

are outlined in such a way as to form a dorsal and volar flap In the construction of these flaps, it is better not to be too ambitious It is preferable to make them rather short and broad than to risk necrosis of the tips The flaps are mobilized, exposing the first dorsal interosseous and adductor pollicis

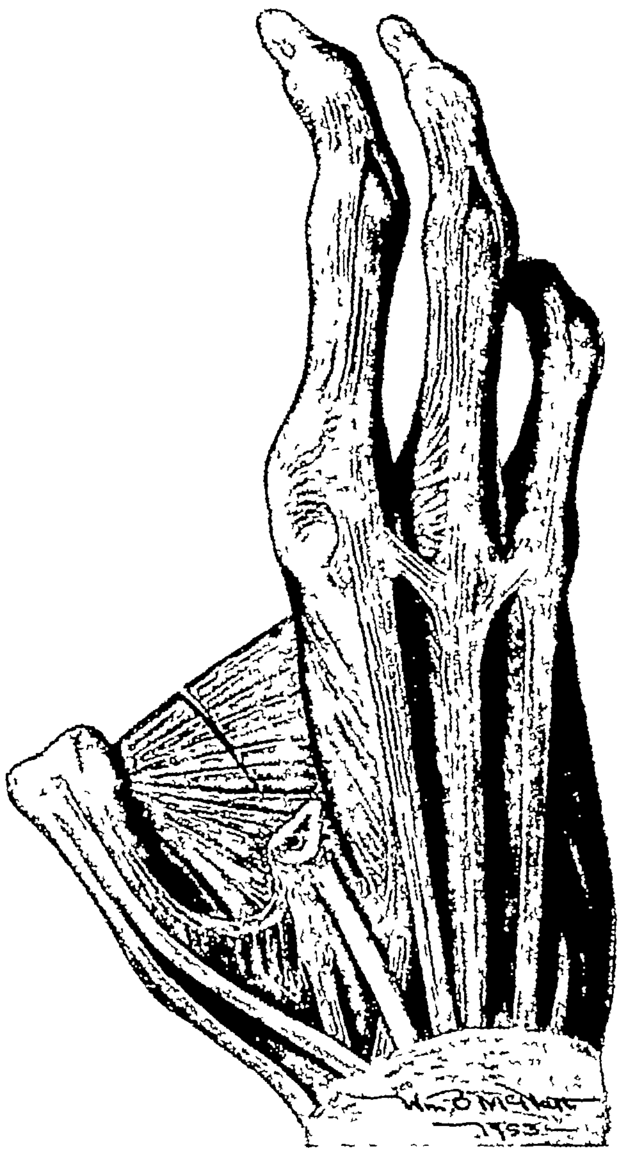


Fig 416 Dorsal aspect Dorsal interosseous muscle has been removed Second metacarpal shortened to create wider cleft. Incision of distal half of adductor muscle indicated

muscles The interosseous muscle is excised The next step is the removal of the second metacarpal bone, with the exception of the base, to prevent collapse of the metacarpal arch and to preserve the insertion point of the extensor carpi radialis, care should be taken not to injure the radial artery as it crosses the interspace between the first and second

function The adductor muscle which forms the bulk of the muscle filling the space between the first and second metacarpal bones should be removed only partially otherwise the pincer action of the first metacarpal would be lost The muscle originates along the entire length of the

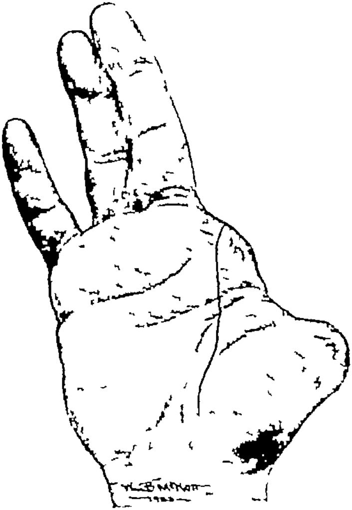
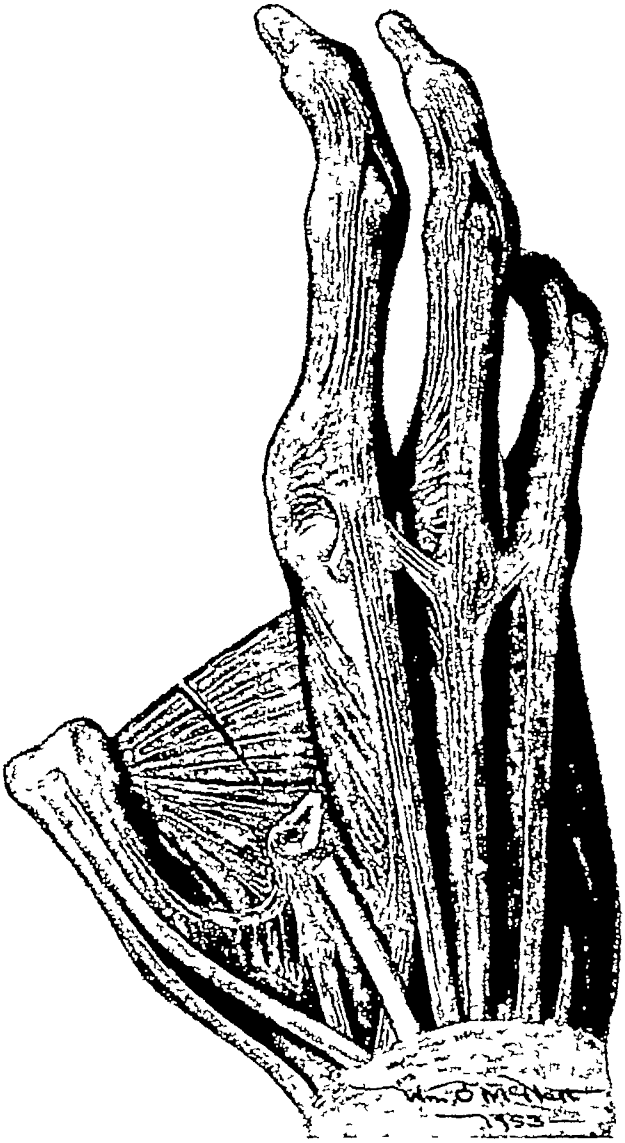


Fig. 415 Volar incision.

third metacarpal bone and with a smaller head at the carpal bone and inserts at the head of the first metacarpal In other words it bridges the second metacarpal hence the second metacarpal bone can be removed without disturbing the function of the adductor muscle To deepen the cleft Bunnell transfers the inserting point from the head of the first metacarpal more proximally *Others incise that part of the muscle which* originates along the third metacarpal bone The author has found this latter method simple and effective In certain cases (see p 801) partial removal of the second metacarpal bone is advantageous to widen the cleft

Technic (Example Absence of Phalanges of Thumb and Index Finger) (Figs. 414-416) (compare with Case 161 p 1072) The incisions

are outlined in such a way as to form a dorsal and volar flap In the construction of these flaps, it is better not to be too ambitious It is preferable to make them rather short and broad than to risk necrosis of the tips The flaps are mobilized, exposing the first dorsal interosseous and adductor pollicis



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metacarpal bones The adductor pollicis muscle is now incised It has an oblique and a transverse portion the latter forms the bulk of the muscle. It is incised until the oblique portion of the muscle is reached which is left intact. The incised portions of the muscle are reflected dorsally to cover the stump of the second metacarpal bone, or both portions are excised. The skin flaps are now carried around the cor responding raw surfaces and sutured to the opposite wound edges They with a thick split skin graft. A heavily padded pressure dressing is applied.

After Treatment The dressing is removed after ten days and active motion exercises are started

Variations If too much of the adductor muscle is incised and the pincer action of the first metacarpal bone is weakened, which has happened in one of our cases the patient is able to rotate the thumb but adduction re sembles the action of a loose pair of scissors Should this be the case the grip can be tightened appreciably by transfer of one of the flexor tendons of the missing index finger or the sublimis tendon of the third finger led dorsally to be attached to the dorsal side of the first metacarpal bone (for method of attachment, see pp 727–728) (Case 163 p 1071)

It is a generally agreed upon practice to remove the second metacarpal to widen the cleft as described in the foregoing in patients in whom aside from the thumb phalanges the phalanges of the index and third fingers are absent. In patients in whom all fingers are absent the author s experience is that the removal of the second metacarpal is of no advan tage It narrows the hand the patient cannot grasp larger objects owing to the absence of grasping power of the fingers and he has difficulty in grasping smaller objects since the cleft at the bottom is too wide and cannot be closed completely Therefore in patients with all fingers lost at the metacarpophalangeal joints it is better to leave the second meta carpal behind (Cases 162 163 pp 1070 1071) On the other hand in cases where the thumb is preserved but the second third or all fingers are miss- ing the second metacarpal should be removed since the loss of grasping finer objects is outweighed by the increase of width and hence by the in crease of the grasping power (Case 164 p 1072)

If all fingers are lost and the metacarpal bones are covered with un stable scars the latter must be replaced with a well padded abdominal flap the flap can be constructed in such a way that after its severance at the time of its adjustment phalangization can be carried out in the same stage If the flap has also to replace and form the web the second meta carpal must be removed since the padded flap—even if thinned out later on—would fill out the grasping space. The second metacarpal bone with

the exception of its base, is removed at the time of the transfer of the flap (Case 164, p 1072)

If the thumb metacarpal is too short, it should be lengthened with an iliac-bone graft or by utilizing part of the second metacarpal bone, if excision of the latter is contemplated (Cannon, Graham, Brown), or by the Hilgenfeldt method (see below) The former procedure is carried out through a dorsal incision, so placed that it can be used again at the time the cleft is created However, if the skin is too short over the first metacarpal stump, a so-called "cock-hat" flap (Lewin, Gillies) can be used to lengthen it It is raised from a curved incision across the radial border of the hand, 2 5 cm (1 inch) or more proximal to the tip of the stump of the first metacarpal This flap is raised like a hood After the metacarpal is lengthened with a bone graft, the hood of skin is placed over it, and the secondary defect on the radial side of the hand is skin-grafted The bone graft is fixed in opposition and minimal angulation, using Hilgenfeldt's dovetailing method (Fig 407) Additional fixation is accomplished with the use of oblique Kirschner wires

Hilgenfeldt lengthens the first metacarpal with part of the second metacarpal (if the phalanges of the index finger are absent) by using the underlying principles of his method of thumb substitution

Technic (Compare with Figs 403–408) About 1 cm. (3/8 inch) proximal to the metacarpal head, a transverse incision is made which circumscribes the metacarpal head about two thirds of its circumference The incisions are then continued on each side of the bone into the palm in a way similar to that described on p 787, so that a skin flap about 1 cm (3/8 inch) wide is made The branches of the volar digital arteries are located in the cleft between the second and third fingers If the third finger is still preserved, the branch is divided just beyond its ramification Location of the digital nerve is the next step Nerves and vessels are then dissected free proximally by incision of the vertical septa of the palmar fascia until the superficial volar arch is reached The shaft of the second metacarpal bone is exposed from a dorsal longitudinal incision and, after division of the extensor tendons, is severed either with a rongeur or with a Gigli saw In calculating the proper length, it is necessary to make allowance for the dovetailing of the bones (see p 789) About 7 mm (1/4 inch) should be allowed for the formation of the tongue To rotate the bone, it is necessary to detach the first dorsal and the volar interosseous muscles from their insertions and to divide the intermetacarpal neck ligament It is not necessary to divide the flexor tendons at this stage, and it may not be necessary to do it at all From the base of the skin flap, an incision is made to the stump of the first metacarpal bone (compare with

metacarpal bones The adductor pollicis muscle is now incised It has an oblique and a transverse portion the latter forms the bulk of the muscle. It is incised until the oblique portion of the muscle is reached, which is left intact. The incised portions of the muscle are reflected dorsally to cover the stump of the second metacarpal bone or both portions are excised. The skin flaps are now carried around the corresponding raw surfaces and sutured to the opposite wound edges They with a thick split skin graft. A heavily padded pressure dressing is applied

After Treatment The dressing is removed after ten days and active motion exercises are started.

Variations If too much of the adductor muscle is incised and the pincer action of the first metacarpal bone is weakened which has happened in one of our cases the patient is able to rotate the thumb but adduction resembles the action of a loose pair of scissors Should this be the case the grip can be tightened appreciably by transfer of one of the flexor tendons of the missing index finger or the sublimis tendon of the third finger led dorsally to be attached to the dorsal side of the first metacarpal bone (for method of attachment, see pp 727–728) (Case 163 p 1071)

It is a generally agreed upon practice to remove the second metacarpal to widen the cleft, as described in the foregoing in patients in whom aside from the thumb phalanges the phalanges of the index and third fingers are absent. In patients in whom all fingers are absent the author s experience is that the removal of the second metacarpal is of no advantage. It narrows the hand the patient cannot grasp larger objects owing to the absence of grasping power of the fingers and he has difficulty in grasping smaller objects since the cleft at the bottom is too wide and cannot be closed completely Therefore in patients with all fingers lost at the metacarpophalangeal joints it is better to leave the second metacarpal behind (Cases 162 163 pp 1070 1071) On the other hand in cases where the thumb is preserved but the second third or all fingers are missing the second metacarpal should be removed since the loss of grasping finer objects is outweighed by the increase of width and hence by the increase of the grasping power (Case 161 p 1072)

If all fingers are lost and the metacarpal bones are covered with unstable scars the latter must be replaced with a well padded abdominal flap the flap can be constructed in such a way that after its *severance* at the time of its adjustment phalangization can be carried out in the same stage If the flap has also to replace and form the web the second metacarpal must be removed since the padded flap—*even if* thinned out later on—would fill out the grasping space The second metacarpal bone with

fer of an abdominal flap to the hand to provide stable coverage of the raw area over the transferred flexor tendon at the junction of digit and palm

Cineplasty

Cineplastic operations are performed on amputation stumps of the upper extremity for the purpose of utilizing the potential and residual forces within the muscles of the stump to activate a prosthesis In 1896, Vanghetti of Italy, in an attempt to help his countrymen who were mutilated in the first Abyssinian war, conceived the idea of cinematization of the amputation stump of the forearm Realizing that there were still intact muscles, rendered useless after the amputation, he isolated the distal tendinous parts, enclosed them with covering skin, and connected them with a specially constructed prosthesis Others have endeavored to improve the technic

The great credit, however, for placing the method upon a scientific basis, and developing it for practical purposes, goes to Sauerbruch (1915). He described the development of his ingenious thoughts in detail in his fascinating memoirs By testing the potential power of a muscle or muscle group at various levels of the extremity, he succeeded in developing favorable combinations of muscle groups to be used for activation He also developed the operative method and the construction of suitable prostheses His method found many followers Kessler did the pioneer work in this country For many years, he was the lone person in this country to do this operation His efforts and enthusiasm became greatly rewarded. Nissen, in collaboration with Bergmann, published the experiences they had had with various methods of cineplasty in a well-illustrated monograph

SKIN-MUSCLE CANALIZATION (SAUERBRUCH'S METHOD)

While the original Sauerbruch method is still the standard, improvements have been made Considerable work in cinematization had been done in Germany during World War II on several thousand amputees in two centers—one in Berlin under Sauerbruch, and the other in Munich under his distinguished pupil, Lebsche To study their methods and results and to investigate the possibilities of improving the cineplastic technic and construction of the artificial limbs, the United States Army sent Dr Alldredge, accompanied by Colonel Peterson and certain engineers, after the war to Germany As a result of their findings, the Committee on Artificial Limbs of the National Research Council began a research program on cineplasty It started with a revival of interest in muscle physiology in relation to the mechanical needs of the prosthesis,

Fig 403) The scar over the stump is removed and the bone is exposed if necessary with a dorsal incision The incision is carried to the thenar muscles The radial wound edge remains undisturbed while the ulnar one is undermined to form a flap This flap formation has two marked advantages First, the thenar muscles are well-exposed secondly this skin flap can later on be pulled into the cleft between the first and second metacarpal bones to form a web of normal well padded skin

After the stump of the first metacarpal has been sufficiently exposed dovetailing is performed as described (p 789) The transferred meta carpal bone should be in opposition to the other fingers and in slight flexion It is held transfixed with an oblique Kirschner wire Complete hemostasis is now performed after release of the tourniquet If the flexor tendons of the second finger and lumbrical muscle are in the way they should be divided The skin is now draped around and sutured in place Any remaining raw surface is covered with a split thickness skin graft. A dorsal molded plaster cast is applied reaching from the forearm to the thumb The cast remains for six weeks

Substitution of Toe for Thumb

This method which has rare applicability was first employed by Nicoladoni Others have followed it and used it also for other fingers or for part of a finger (Oehlecker Riedel Mühsam v Eiselsberg Blair Byars Gillies, and Young) By modifying the method Clarkson was able in one of his cases (congenital adactylia) to substitute the toes for the fingers by a five toe transfer

Technic (Clarkson) A delayed dorsal flap is utilized on the foot of the same side, with its peripheral end 3 8 cm. (1½ inches) distally over the metatarsophalangeal joint of the (great) toe to be transferred. When it is transferred the donor area is covered with a split skin graft. At the hand the dorsal skin is excised proximal to the digit (to be restored) to receive the dorsal foot flap With the knee and hip in acute flexion the hand is brought to the foot The toe extensor tendons are attached to the cut tendons of the missing finger The flexor hallucis longus tendon is cut behind the ankle threaded through the metatarsophalangeal joint then through the thenar eminence and wrist to be attached to the flexor unit at the forearm The dorsal toe flap is then sutured in place followed by strapping the extremities for immobilization Detachment of the toe from the foot is performed in stages After two weeks the vascular pedicle on one side is severed after two more weeks the other one is divided this is followed after two more weeks by disarticulation of the toe closure of the distal dorsal skin defect at the foot with a split-skin graft and trans-

The flaps are cut so that they contain subcutaneous fat tissue and deep fascia to secure an ample blood supply (Fig 417)

Construction of Upper-Arm (Biceps-Muscle) Canal (Fig 417–420, Case 165, p 1073) First, the skin tube is made by everting the wound edges of the rectangular flap The first suture is laid through the terminal wound edges, and consists of silk or nylon (Fig 418) The following su-

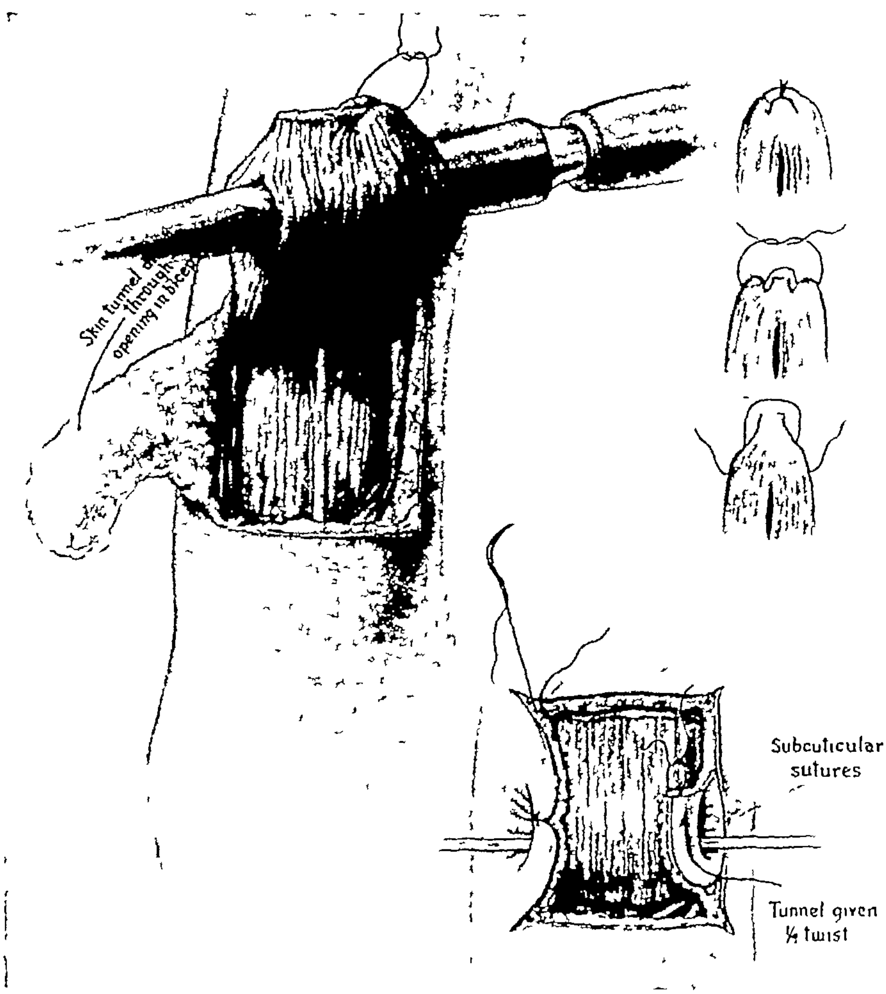

Fig 419 The flap becomes a skin tube by reversing the flap and suturing the sides The muscle is then liberated from its distal attachment and the surrounding fascial septa The tendinous end should be imbricated to provide a smooth non-adherent surface (A. W Spittler and I E Rosen, J Bone & Joint Surg)

ture, starting from the periphery toward the base of the flap, is a row of interrupted suture or a removable running percutaneous wire suture, which is laid through the skin edges to hold the tube together The muscle is now perforated The perforation is enlarged with a muscle dilator (rectal dilators of various thicknesses do as well) (Fig 419) The perforation must be made larger than the skin tube, but should not cause perforation of the muscle. The muscle should be perforated

in which Dr Verne T Inman and his co-workers at the University of California had been most interested and culminated in the excellent results achieved by Colonel Spittler and his co-workers at the Cineplastic Center at Walter Reed Army Hospital It became evident, however that such results are possible only by integrated teamwork as demonstrated by the extensive end result study of Brav Spittler and others These results require proper selection of the patient, his cooperation a well executed operation well-constructed prosthesis and training in the use of the prosthesis All those experienced with the method come to the conclusion that a patient provided with a muscle motor (cineplasty) gets better use from the prosthetic device than with the usual shoulder-strap control.

The three most important improvements over the original Sauerbruch method are (1) a modification made by Lebsche consisting of liberating or dividing the distal insertion or attachment of the muscle through which the tunnel was placed thus giving the muscle more strength and excursion (2) a very much larger skin tube through which the peg is placed—the larger the tube and the peg the less pressure there is on the skin with movement of the prosthesis (3) the use of the biceps as a motor whether or not the forearm stump can be utilized The results which Lebsche and later on Colonel Spittler demonstrated with this latter method were most impressive

Selection of Muscle-Motor Sites Of paramount importance are well functioning muscles Generally speaking, only those muscles should be utilized which are not needed for the movements of the stump itself. Flexor muscles are used for closing extensor muscles for opening the artificial hand Today however the prostheses are constructed with a spring mechanism to be used for opening the hand hence construction of an extensor muscle canal can be dispensed with The stump itself must be in good condition and of proper length If the stump is too short the operation is unlikely to be successful since the excursion of the muscle tunnel is in direct proportion to the length of the muscle through which the tube passes and the strength of the motor is in direct proportion to the diameter of the muscle belly Hence the longer the stump the better the function of the muscle motors

In long forearm stumps the musculus flexor sublimis just above its musculotendinous juncture was formerly preferred as the muscle motor Recently however as already mentioned even in long or short forearm stumps, the biceps is preferred as the muscle motor (Case 165 p 1073) since it has more strength and excursion than the forearm flexors Extensor motors are dispensed with

the patient is advised to do active muscle exercises with the motor muscle After complete healing, the rod is inserted, pull is exerted on it by the patient or somebody else, and the patient performs passive motion exercises Later on, the rod is attached to a weight for hanging or horizontal pull, the weights to be increased daily The canals are cleansed daily

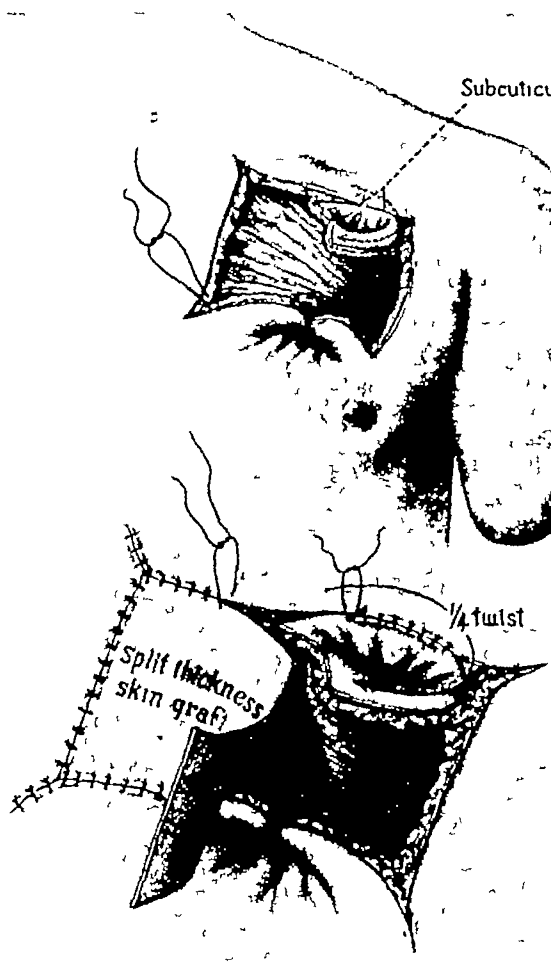

Fig 423 The skin tunnel is drawn through the opening in the pectoralis and the mouth of the tunnel is sutured to the adjacent skin The denuded muscle is covered with a split-thickness skin graft (A W Spittler and I E Rosen, J Bone & Joint Surg)

with applicators, using soap, water, and alcohol (no powder) A cineplasty prosthesis is fitted in the meantime. Until recently, the only one was the German type, which was very delicate and lacking in functional qualities Improvements have now been made in this country, mainly at the Army Prosthesis Research Laboratory under Colonel Spittler and his group at the Walter Reed Army Medical Center and at the Henry Kessler Institute There are orthopedic firms, such as Hanger, etc , which

through the distal end of the muscle fibers which is considerably distal to the skin tube. The elbow is now flexed to shift the biceps perforation proximally to the level of the skin tube. By retracting the distal wound edge the biceps tendon and the lacertus fibrosus are severed, and the muscle is well liberated from the surrounding fascial septa. If the elbow is now extended the biceps perforation will remain at the level of the skin canal Before the skin tube is pulled through the muscle

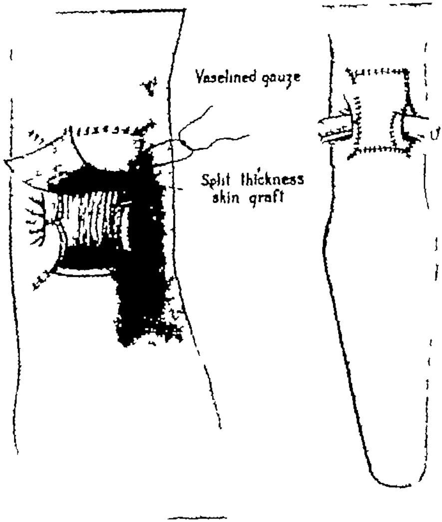

Fig 420 A split-thickness skin graft is adequate to cover the exposed muscle surface. It should be noted that the distal end of the skin tube is well opened up over the muscle to shift the pin pressure from the suture line. (A. W Spittler and L E. Rosen, J Bone & Joint Surg.)

perforation the tendinous end is carefully imbricated (Fig 419) to cover the raw tendon stump. In this way a smooth nonadherent surface is provided The skin tube is then pulled through the perforation with the help of several traction sutures laid through the rim of the tube. To place the seam of the tube away from the pressure pull of the rod when the prosthesis is used the traction sutures should rotate the tube so that

ful, a hideous thing, and patients often refuse the operation for cosmetic reasons. For this and other reasons, the operation was not popular in this country However, more interest has been stimulated since World War II, mainly due to the studies of the U S Army group under Aldridge, who had been sent to Germany to study the results of the cineplastic operations in Germany during the war, and particularly due to

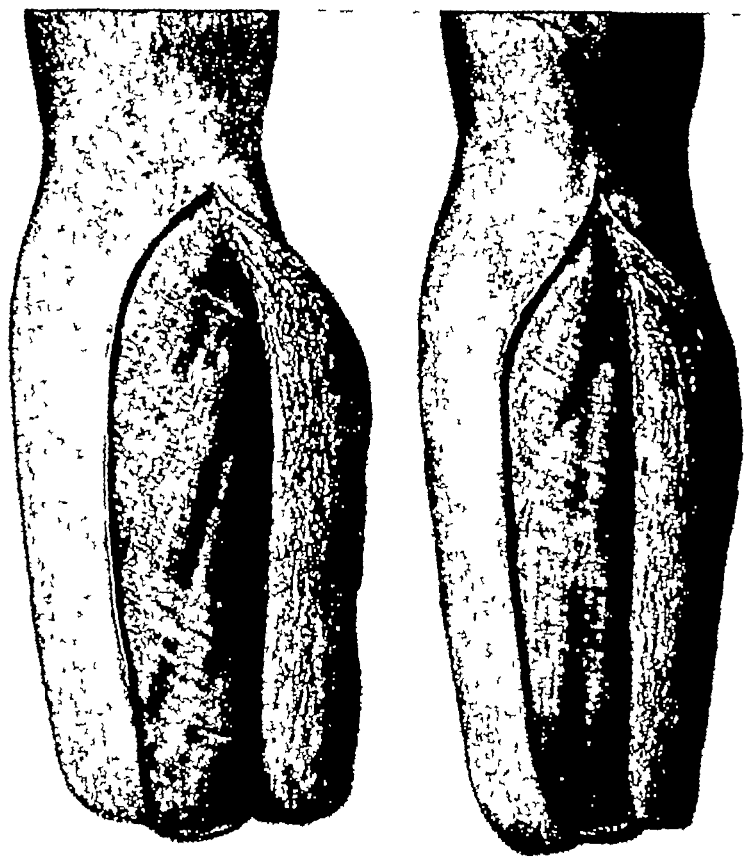

Fig 425 Forcipitation of forearm after Krukenberg-Kallio Volar and dorsal skin flaps outlined

K. E Kallio, of Finland, who with 45 personal cases, has had the largest experience with the Krukenberg method Kallio visited this country in 1948, and demonstrated the technic and his results with an impressive moving picture, and followed up the subject later on in an extensive article Zanobi of Italy and Sung of China corroborate Wallio's enthusiasm about this subject

The forcipication of the forearm is in competition with cinematization It has been argued that the patient has greater usefulness of the stump and a stronger grip after cineplasty than after forcipication, this, according to Kallio's experience, appears not to be true An added

furnish adequate prosthesis according to the specifications of the Prosthesis Research Laboratories

Forcipication of Forearm Stump (Krukenberg's Method)

This method consists essentially in splitting the forearm between ulna and radius and mobilizing the radius. The radius now moves inde

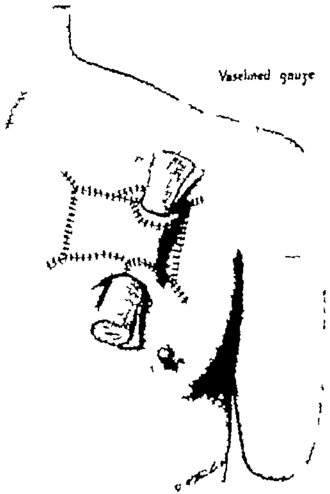

Fig. 424: A small roll of xeroform gauze is inserted in the tunnel. After ten or fourteen days, exercise is started with a forceps attached to each end of the dressing in the tunnel. (A. W. Spittler and I. E. Rosen, J. Bone & Joint Surg.)

pendently from and against the ulna, hence its mobility can be used in a forceps-like manner to grasp things. The method can be successfully employed only in long forearm stumps. The optimal length of the latter should be two thirds or one half of the forearm. Stumps which are too long are not suitable either. The best results are achieved if the distances between the tips of the branches and the opening angles are between 10 and 15 cm. (4 and 6 inches). This pincer arrangement is, although use

190 times a minute), a good sensation, and a good blood supply of the branches

The operation was formerly performed in two stages Kallio and Thompson, however, have recently advocated the use of a free skin graft to cover the raw dorsal surface of the ulna branch instead of using an abdominal flap Hence, the operation can be completed in one stage In

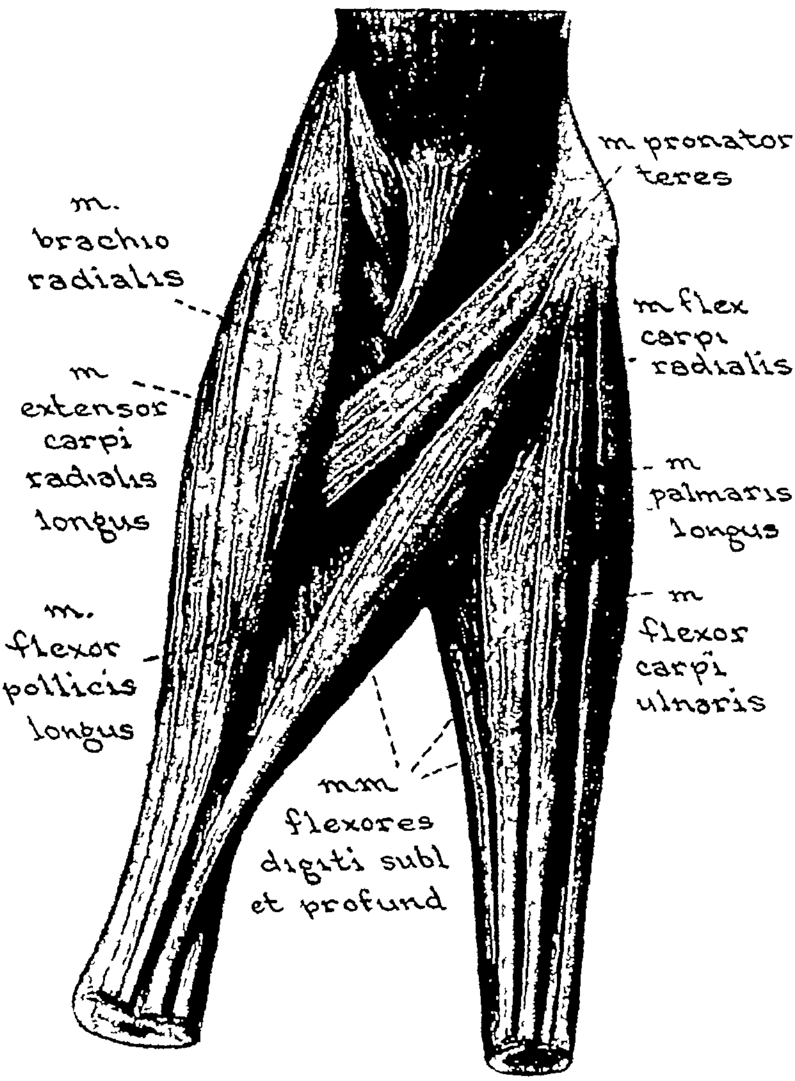

Fig 427 Volar view of split forearm

selected cases, the forcipication can be performed at the time of the amputation of the forearm Kallio does not sacrifice some of the muscles, as Krukenberg originally advised, Kallio and Langenskiold devised a different way of skin incisions and development of local flaps so that the contact surfaces of the branches can be covered with local skin, hence have normal sensation

advantage of forcipication is a normal sensation of the stump so that this method becomes the method of choice in blind forearm amputees. Everybody who has experience with forcipication agrees that the best results are achieved in bilateral amputees or in those who have had one forearm amputated and the other hand badly damaged A successful

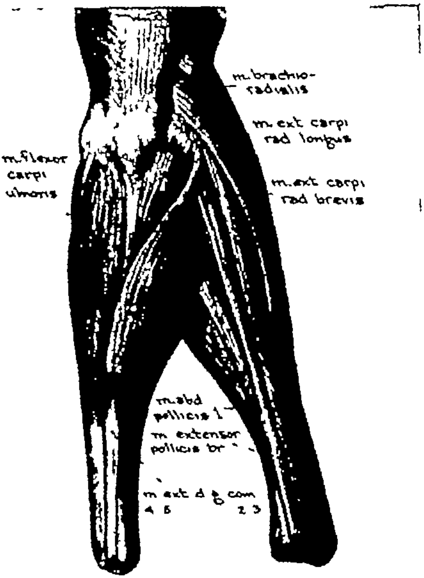

Fig. 426 Dorsal view of split forearm.

operation results in a forearm stump supplied with grasping function a sufficient opening angle of from about 30 to 45 degrees, a straight, hinge like abduction and adduction when the stump is either flexed or ex tended a good grasping power (about 5 to 10 kg) a rate of moving the pincers approaching that of the normal human fingers (about 100 to

be avoided. Kallio found the following method helpful. The radial branch of the claw is grasped tightly, and the patient is asked to bend both his elbows simultaneously, experience has shown that by this motion the ulna is invariably adducted straight against the radius The ulna is then fixed, and the patient is asked to straighten the elbow joint To enable the patient to make good use of the hand even during the period of training, he is made to write with a pen furnished with a wedge-shaped handle of cork His fork, knife, and spoon have special handles (Case 166, p 1074) The patient is given a prosthesis only when the new hand is fully trained and the patient desires a prosthesis Kallio found value in a combined prosthesis, consisting of a cosmetic hand and a detachable utility hook

Congenital Malformations of Hand

Congenital malformations of the hand may be roughly grouped into defective development (hypoplasia and aplasia) and excessive development (hyperplasia) The cause is unknown for a great many of these lesions, in spite of elaborate theories to explain their origin Hence, a satisfactory classification is impossible. Only a brief description of the commoner deformities and their surgical treatment, if such is possible, will be presented For details, authoritative publications about this subject should be consulted, such as those by Kanavel, Birck-Jensen, Barsky, and Kelikian and Doumanian

HYPOPLASIA AND APLASIA

Amputations

Amputations may range from a small part of a phalanx to the entire extremity If the fingers alone are involved, some of the reconstructive operations mentioned on pp 783–804 may be applicable, and should be considered In other cases, artificial appliances replacing the absent member are the better choice (see also Cineplasty, p 804, Forcipication, p 813)

Clubhand

Absence of Radius: Kanavel distinguishes four types: (1) complete absence of the radius, (2) a rudiment of the upper end with more or less of the diaphysis present, (3) a rudiment of the lower end with more or less of the diaphysis present, and (4) absence of the diaphysis.

The commonest type is complete absence of the radius or the greater part of its distal portion with radial deviation of the ulna and radial clubhand Gegenbauer's primitive-ray theory may find support if, as so often, absence of the radius is accompanied by suppression of development of other components of the first ray, which includes radius, os naviculare, os multangulum, the first metacarpal bone, and the thumb The ulna

Technic (Figs 425–427 Case 166 p 1074) With a pneumatic tourniquet applied a longitudinal incision is made on the dorsal aspect of the forearm along the edge of the ulna (Fig 425 *b*) On the volar aspect the incision is made slightly radially from the midline (Fig 425 *a*) At the proximal end these incisions are curved the dorsal incision radially the volar ulnarly On the dorsal aspect the skin is then mobilized slightly radially and on the volar aspect slightly ulnarly so as to form two flaps of skin The incision is then deepened on the extensor side (Fig 426) It penetrates between the muscles so that the musculus extensor digitorum communis is divided into a radial and an ulnar part The radial contains the tendons of the second and third finger the ulnar the tendons of the fourth and fifth fingers On the ulnar side are also the musculus extensor carpi ulnaris. On the radial side remains the musculus brachioradialis musculus extensor carpi radialis (longus and brevis) and also the abductor and extensor muscles of the thumb The incision is now continued on the flexor side (Fig 427) The musculous flexor carpi radialis remains on the radial side the musculus flexor digitorum sublimis and the musculus flexor digitorum profundus are divided into radial and ulnar parts On the radial side also remains the musculus flexor pollicis longus The main trunks of the vessels do not come in sight. The peripheral part of the median nerve is resected The corresponding muscle groups are held together with a few sutures The ligamentum interosseum is divided along the ulna The arteria interossea should not be injured. When the splitting of the stump is finished the dorsal flap is turned around the radial branch and has sufficient length to be sutured to the radial edge of the volar incision Should this, however not be possible the skin edges are approximated as much and as safely as can be done, and the remaining raw area is skin-grafted. The volar flap is too narrow to cover the entire branch but it should have sufficient width to cover the volar aspect. The remaining dorsal raw surface of the ulna is covered with a large thick-split graft A pressure dressing is then applied to the grafted area

After Treatment The dressings are removed on the tenth postoperative day and active exercises should be started immediately In this operation the forearm stump is cleft and formed into a kind of forceps the radial branch of which is made to move actively against the ulnar branch The majority of muscles however surrounding each branch move rather in pronation and supination than in abduction and adduction By mere pronation and supination objects are grasped with difficulty since they are grasped with a twist. Hence the exercises from the very beginning must aim at abduction and adduction rotation must

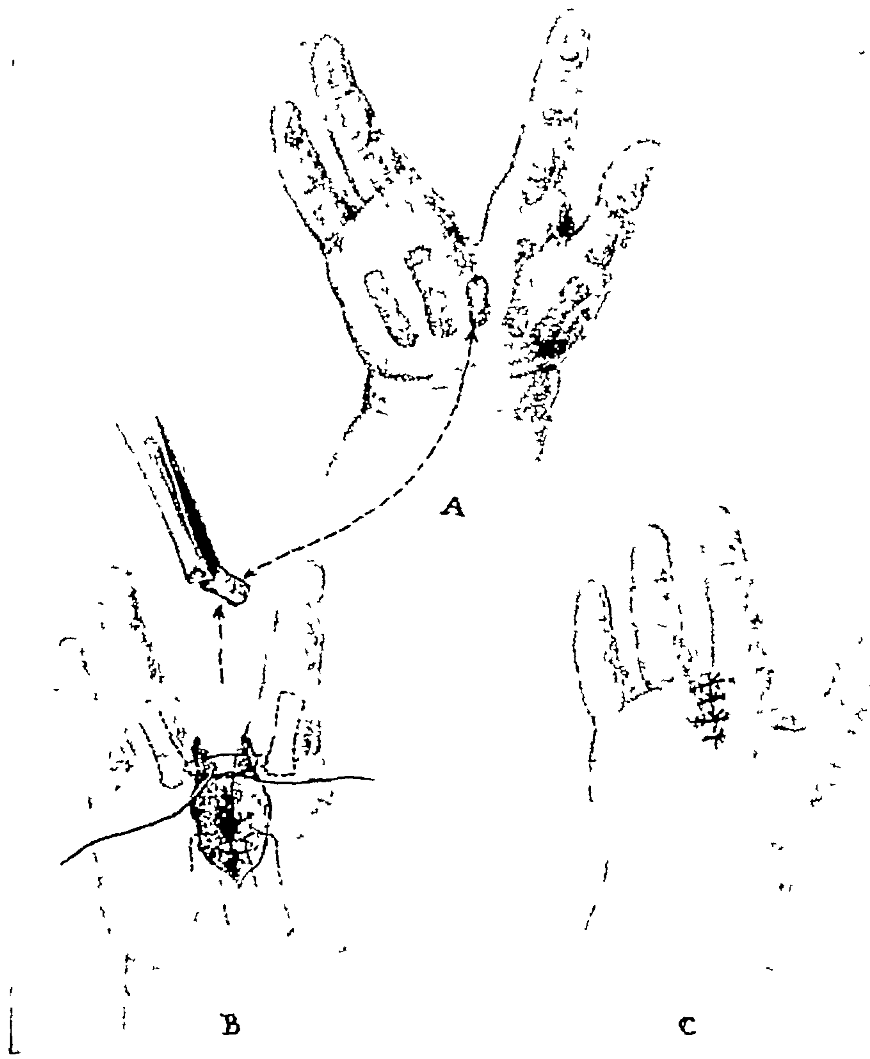

Fig 428 Cleft hand (lobster hand) Aplasia of middle finger and parts of its metacarpal bone Removal of metacarpal stump and approximation of radial and ulnar elements. (A B Kanavel, Arch Surg.)

and other bones of the upper extremity and the shoulder girdle may also be deformed as well as other parts of the body

Regarding the muscular system it is not uncommon to find absence fibrosis or contraction of the most radial muscle bodies. The biceps may be absent and other muscles disorientated The radial artery is often absent and nerves and other arteries are disorientated

Absence of Ulna This involves not only the ulna but, in varying degrees the ulnar elements, with ulnar deviation of the radius and ulnar clubhand

Treatment If the clubhand deformity is without bone defects, tenotomies and tenoplasties combined with Z plasty (Bunnell and Dehne) splinting and massage of the contracted muscle are usually sufficient In severe forms with bone defects function of the arm may be improved by Z plasty for lengthening the contracted skin (Bunnell and Dehne) and by osteoplastic methods such as osteotomy arthrodesis and bone transplantation (methods of Romano Bardenheuer Steindler Albee Ryerson Kanavel and others)

Cleft Hand (Lobster-Claw Hand)

The simpler and classic type is aplasia of the middle finger and parts of its metacarpal bones. But every degree of hypoplasia may be found from this simple loss to complete loss of all medial elements with rudimentary elements of the first and fifth digits remaining alone Association with syndactylism polydactylism and other deformities has been reported

Technic (Figs. 428 429) If the deformity is associated with other malformations the operation must be divided into several stages. If the cleft extends into the palm a wedge-shaped incision is made extending from the proximal phalanx down through the palm A deep dissection is then made of the metacarpal bone of the affected finger and this is removed down to its base The next object of the procedure is approximation of the fingers of the radial and ulnar sides (see Fig 428) This position is maintained with slings of fascia lata around the metacarpals and proximal ends of the phalanges of these fingers (Meyerding and Dickson) The wound is closed in layers Circular adhesive strips are placed around the dressed palm and fingers to hold the bones together They are left in place for at least three weeks.

If there is no syndactylism of the index finger and thumb Kanavel devised a procedure for the lengthening of the web between thumb and index finger The first part of the procedure is the same as just described. From the radial edge of the cleft another incision is made which passes around the base of the proximal phalanx of the index finger (see

his cases the deformity was associated with insufficient circulatory supply to the fingers Consequently, only in extreme cases, with definite functional handicap, should repair by surgery be attempted This is best done by arthrodesis of the involved joint in the position of function (Fig 430)

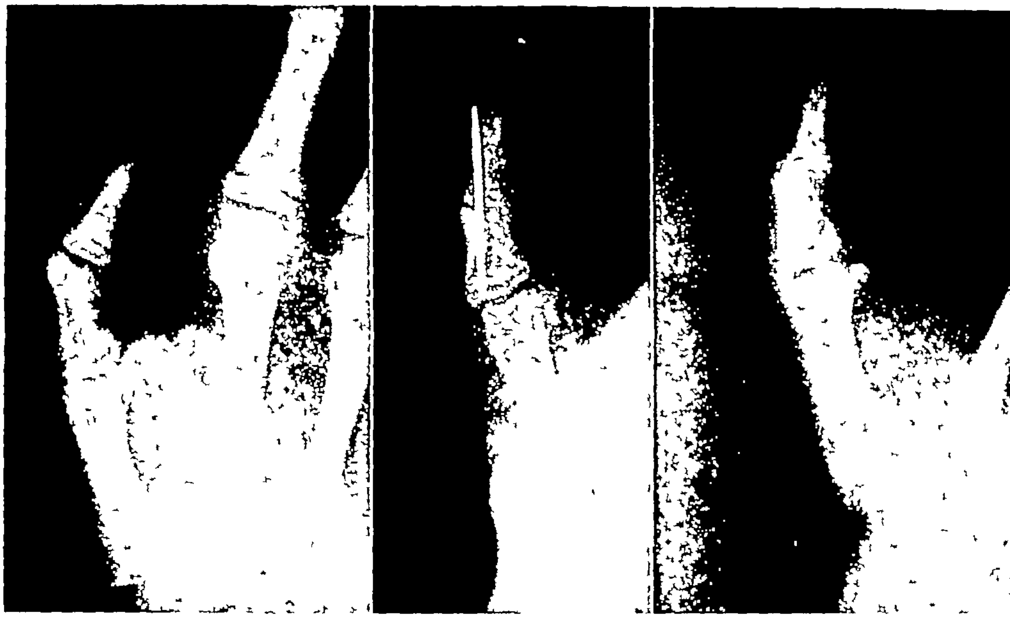

Fig 430, *a-c* Clinodactylism of thumb, repaired with arthrodesis of terminal joint in the position of function

Constricting Furrows

These so-called "amniotic" furrows are constricting bands, consisting of fibrous tissue which may encircle the entire extremity In the hand, as elsewhere, they may need removal, if such is possible The Z-operation is recommended The long arm of the Z is placed within the groove, after exchange of the triangles (see Fig 53), the groove is displaced vertically (Case 138, p 1038)

Brachyphalangism, Hyperphalangism, Symphalangism

Meyerding's illustration of these various deformities is self-explanatory (Fig 431) Surgery is rarely ever employed for these conditions

Syndactylism

This deformity and its correction have been described on p 703

Polydactylism

Polydactylism may roughly be divided into a central and a marginal form. The marginal form—that is, an extra thumb or little finger—is by

Fig 429) The skin is now dissected away from the index finger to form a dorsal and volar flap When the index finger and its metacarpal bone is transferred over to the ring finger it slides between these two skin flaps, thus leaving skin on the radial side of the index finger for a good web between the index finger and the thumb

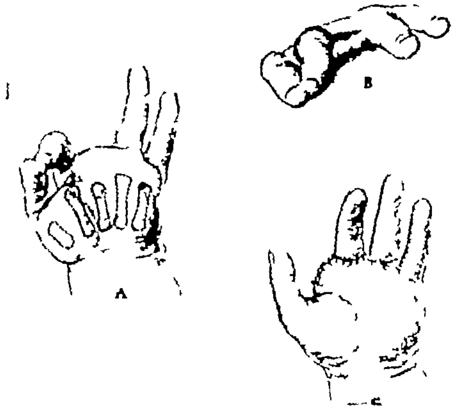

Fig. 429 Cleft hand (lobster hand) Aplasia of middle finger and syndactylism of index finger and thumb. After removal of third metacarpal bone incision is made around base of proximal phalanx of index finger Skin is now dissected away to form dorsal and volar flap and second metacarpal bone approximated to that of fourth finger (A. B. Kanavel Arch. Surg.)

Clinodactylism

This is most often found in the distal joint of the fifth finger It is probably due to disorientation of the epiphysis, producing improper alignment of the joint surfaces and changes in the capsule resulting in contracture of the joint In early life the condition can be corrected by proper external or internal (intramedullary pin) splinting Later however surgery is the only choice consisting in severance of contracting bands, tendon lengthening and sometimes skin-grafting and wedge osteotomies with insertion of chips of bone to elevate the depressed joint surface The author however sounds a note of warning since in two of

extra digit may result in a flail finger, unless the tendons of the former are transferred Hence, preservation of function should be the primary consideration. The operation is usually carried out before the child goes to school (Figs. 432, 433)

An oval incision is made at the base of the joint capsule of the extra digit, and tendons are exposed The tendons are severed and permitted

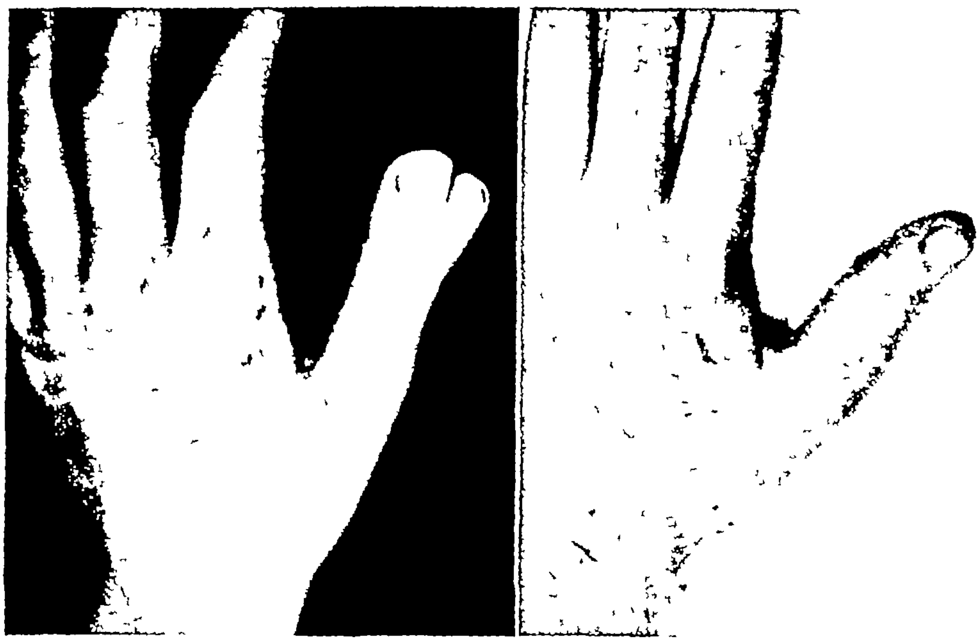

Fig 432 Bifurcation of distal phalanx of thumb with common joint. Before and one year after removal of radial phalanx

to retract unless they are to be used for transfer The joint capsule is opened and the digit disarticulated. The remainder of the capsule is removed and any abnormal bone protrusion also If an extra metacarpal bone is present, the incision is lengthened proximally until the base of the bone is reached The bone is excised and the wound closed in layers.

In case of a bifurcation of the distal phalanx, the extra phalanx, if it is rudimentary, may be simply excised If, however, both phalangeal elements are well formed, the Bilhaut-Cloquet procedure (Fig 433) is advisable This is a V-shaped excision of the median section, together with the inner (opposing) halves of the phalanges, and approximation of the outer halves If the two phalanges are of different length, the incision must be modified to some degree

HYPERPLASIA

Megalodactylism

This deformity appears in two forms one due to bone growth alone (Fig. 434), the other due to neurofibrosis. The latter, being an ele-

far the more frequent type. The extra digit may originate from a metacarpophalangeal joint or there may be a bifurcation of the metacarpal bone or a partial or complete bifurcation of the phalanges Bifurcation of the phalanges is always accompanied by syndactylism The phalanges may be of equal (Fig 433) or unequal size (Fig 432)

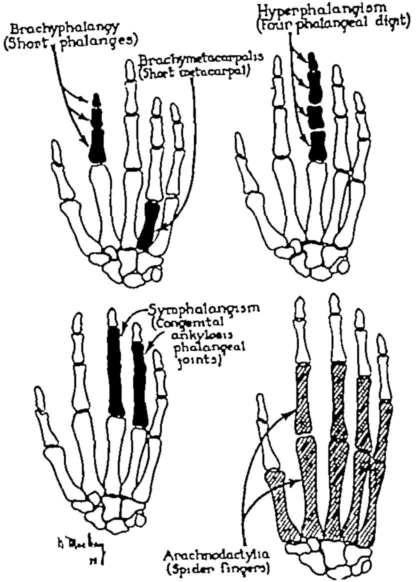

Fig. 431 Types of congenital deformities.
(From H. W. Meyerding and D D Dickson Am. J Surg.)

Treatment Before advisability of surgical treatment is decided careful roentgenological and clinical studies should be made of the function and blood and nerve supply of the two digits Nerves blood vessels and tendons may have atypical positions. At the thumb particularly the intrinsic muscles of the thenar region may be atypical removal of the

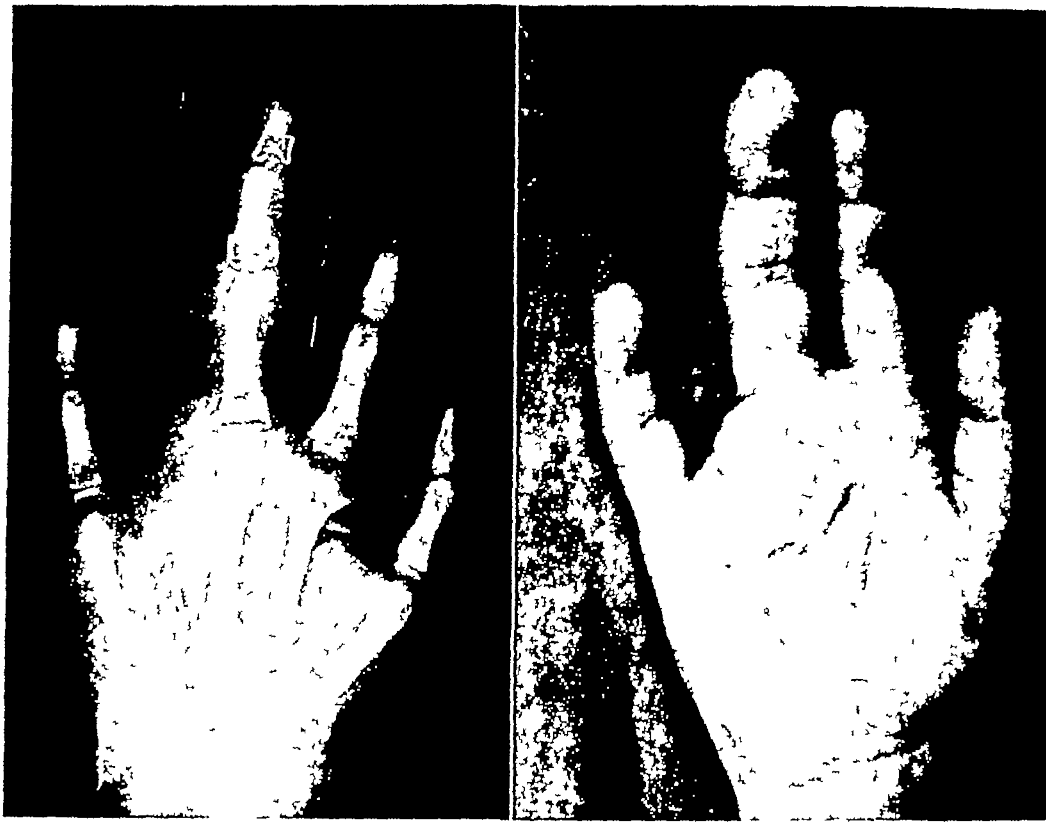

Fig 434, *a*. Megalodactylism (Giant finger) Fourth finger amputated due to rapid growth Epiphyseal lines of third finger stapled to check growth

b This picture is taken three years after roentgenogram, neither stapling nor irradiation checked growth Finger has been amputated in the meantime due to increasing radiating pain and "embarrassment"

Arachnodactylism

This condition is well illustrated in Fig 431

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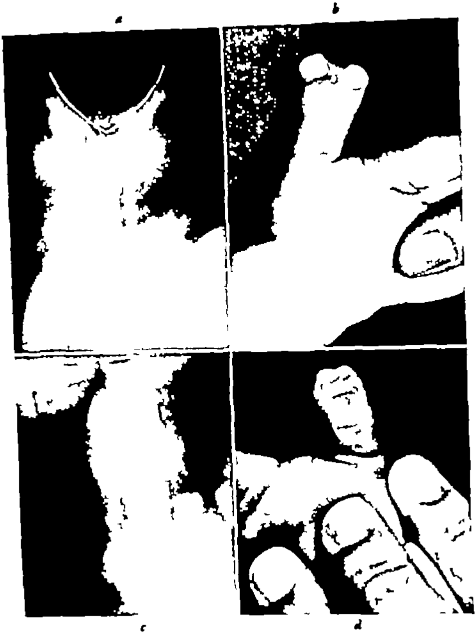

Fig. 433, *a*, *b* Boy seven months of age, with bifurcation of terminal phalanx of right thumb. Both phalangeal elements are well formed. To correct deformity V-shaped excision of median sections, together with inner (opposing halves) of phalanges, and approximation of outer halves were performed (Bilhaut-Cloquet procedure)

c, *d* Four months after operation full function of joint.

phantiasic deformity is a false form of megalodactylism as recognized by x ray examination. In the former the bone overgrowth usually involves the three phalanges the metacarpals are excluded

Amputation of such a finger may be considered owing to its unsightliness or impaired function In the author's experience irradiation of the epiphyseal lines or other measures (Fig 434) to stop growth has not been successful

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SECTION THREE

THE FOOT

weight-bearing There are two places along the sole which are particularly exposed to pressure· the heel and the region over the metatarsophalangeal joints If the graft should break down there, the transfer of a flap may be considered But before constructing the flap, one more conservative measure should be given a trial In one case the region over the fourth metatarsophalangeal joint broke down, forming a shallow ulcer To protect this region from excessive pressure, the patient was advised to wear a flat felt ring, like those worn for the relief of corns and calluses. The ulcer healed immediately, but reappeared after the patient had discarded the protection Permanent relief was accomplished after resection of the head of the fourth metatarsal bone.

Chronic Ulcers

The preferred seat of deep chronic ulcers of the foot is over the heel and the metatarsal pads They are due to excessive pressure (decubital sores, pressure from plaster cast), vascular disturbances (arteriosclerosis, diabetes), infection (osteomyelitis), or to unsuccessfully treated plantar wart The causation of the latter is still obscure. It originates as a papilloma beneath the derma If growing, it gradually perforates the horny plate of the skin, and appears at the outside. Various treatments are recommended, such as cauterization, electrocoagulation, freezing, application of caustics, excision, and irradiation, the latter appears to be the most successful The use of vitamin A has also been recommended, and seems to be worth trying, particularly in cases of multiple warts (see Bibliography under May) Occasionally, the defect from destruction of the growth fails to heal, forming a deep, stubborn ulcer, through which even bones and joints may be exposed In these cases, as well as in other deep ulcers along the foot, transfer of a pedicle flap to cover the defect is the only possibility A thick split graft may rarely be considered, and then only for shallow lesions with sufficient subcutaneous padding still present Any underlying general disease should, of course, be treated first

Smaller defects may be covered by rotation flaps from the neighborhood Farmer uses the entire distal half of the sole as a single-pedicle flap for rotation (Case 167, p 1075) Sometimes in defects at the level of the first or fifth metatarsophalangeal joint, a flap may be slid from the dorsum of the foot, followed by skin-grafting of the donor area, or the bones of the adjacent toe are sacrificed, and the skin of the toe, with or without local flaps, is used for closure of the defect (Greely, Pangman, and Gurdin) For larger defects, flaps must be transferred from distant places. In most instances, the direct transfer of a flap from the lower extremity of the opposite side is possible with the patient in the crossed-leg position.

XXXII

THE STRUCTURES OF THE FOOT

In discussing reparative surgery of the foot, the subject is divided into anatomical units as in the former chapters. It should be emphasized again that the general principles of reconstruction do not differ from those discussed already. Consequently, some of the problems need only brief mention. Others, however, being of special nature, deserve detailed description. Those lesions which belong strictly to the orthopedic field are omitted; for such matters, the reader is referred to the special treatises.

Skin, Subcutaneous Tissue, and Fasciae

DEFECTS

Wounds and Burns

The treatment of wounds has been outlined in Chapter III, that of burns in Chapter IV. The therapeutic principles as applied to the foot are the same. Concerning the late treatment of burns, however, one important point should be stressed. If the sole of the foot is destroyed from a third-degree burn, the question arises as to the wisdom of replacing a tough weight-bearing area, such as the sole, with a split graft. Obviously, this particular area, which is exposed to much pressure, should be protected by the full thickness of the skin and some subcutaneous padding. Hence a flap seems to be indicated. But the transfer of a large flap to cover the entire sole is a difficult problem. The author has been confronted with such a situation and has found it is advisable to cover the raw area, after the granulations have been thoroughly prepared, with a thick split graft. If possible, one large graft should be used to avoid scarring. After the graft has healed well, the patient is permitted some

the flap is ready to be transferred, the defect edges of the ulcer are excised until normal healthy tissue is reached The flap at the thigh is now elevated, and the raw area from which the flap has been taken is covered immediately with a thick split graft, which is held in place with sutures and a pressure dressing The legs are now crossed and the flap sutured to the defect edges of the heel with subcutaneous and skin sutures. The whole area is covered with sterile dressings. To immobilize the legs in this position, a plaster cast is applied, after both legs have been well padded with a layer of cotton The cast is applied as follows A molded plaster-cast splint, consisting of long strips of plaster-cast bandages, is placed along the posterior surface of the donor thigh, leg, and foot. This splint is held in place with circular plaster bandages, which should include the thigh with the exception of the donor site Another molded splint is laid upon the anterior surface of the crossing leg This splint is held in place with circular bandages with the exception of the heel The foot of the crossing leg is now raised somewhat to avoid undue pressure upon the thigh of the donor leg and immobilized in this position with additional circular plaster bandages connecting the extremities with a figure of eight The position of the legs is reinforced and maintained by a connecting plaster-cast splint, which is rolled together to form a rope and placed upon the two extremities

After-Treatment The flap is gradually severed after from ten to fourteen days, using the clamp technic described on p 76, after its final separation, the cast is removed (see also p 71) Adjustment of the free end of the flap, however, should be delayed for another week

Other donor areas are the lateral side of the leg (Case 170, p 1079) and the median half of the calf, occasionally the posterior side of the leg (compare with Case 110, p 1000) The choice depends upon the position in which the patient is comfortable The pedicle is based proximally or distally This is governed entirely by the location of the lesion In females, as already mentioned, the resulting deep scar of the donor area at the leg may be objectionable, hence, the thigh may be preferable If the cross-leg-flap method cannot be used owing to the size of the defect, a tube flap from the chest via the wrist may be possible (see Fig 47) If none of the skin-transplantation methods is possible and the defect is small and suitably located (anterior half of sole), Dickson's procedure, as he uses it for excision of plantar warts, is recommended It consists in removal of a V-shaped section of the foot, including a wide excision of the wart, with corresponding toe and metatarsal bone

Technic (Dickson)· A wide, elliptical incision is made around the plantar wart, extending between the webs of both sides of the toe to be

This method however should be used only if awkward positioning can be avoided that is the joints must be freely movable to permit easy and natural crossing of the legs The calf of the sound side may be used as a donor site in males (Case 170 p 1079) but in females this region is unsuitable owing to the deep and disfiguring scar and the thigh becomes the only possible donor site (Cases 168 169 pp 1076 1078) The cross leg flap method has been thoroughly discussed by Stark If a direct transfer from the other leg is impossible an abdominal tube flap or better still

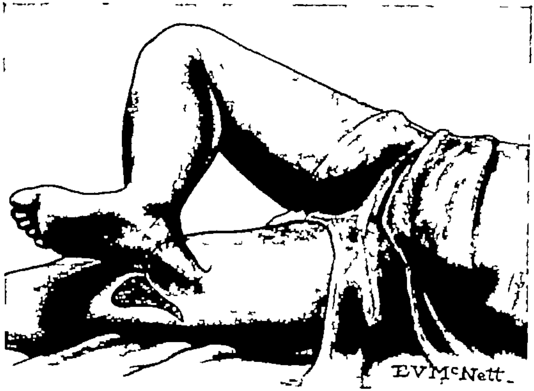

Fig. 435: Transplantation of cross-flap from left thigh to right heel. Flaps with broad pedicles can be raised and transferred in one stage; donor area is skin-grafted in same stage.

an open jump flap (Cannon and others) must be constructed and transferred

Technic (Defect of Heel Covered by Flap from Opposite Thigh) (Fig 435 Cases 168 169 pp 1076 1078) For details of general technic see p 73 If the flap must be long and narrow it is constructed as an open flap and delayed transfer is usually advisable But if it is possible to construct a broad pedicle flap it can be raised and transferred in one stage (Brown and Fryer) (Fig 435) A broad pedicle flap may be constructed (at the median posterior surface of the leg and anterior surface of the thigh for example) more often than was formerly thought possible When

the flap is ready to be transferred, the defect edges of the ulcer are excised until normal healthy tissue is reached The flap at the thigh is now elevated, and the raw area from which the flap has been taken is covered immediately with a thick split graft, which is held in place with sutures and a pressure dressing The legs are now crossed and the flap sutured to the defect edges of the heel with subcutaneous and skin sutures. The whole area is covered with sterile dressings To immobilize the legs in this position, a plaster cast is applied, after both legs have been well padded with a layer of cotton The cast is applied as follows A molded plaster-cast splint, consisting of long strips of plaster-cast bandages, is placed along the posterior surface of the donor thigh, leg, and foot. This splint is held in place with circular plaster bandages, which should include the thigh with the exception of the donor site Another molded splint is laid upon the anterior surface of the crossing leg This splint is held in place with circular bandages with the exception of the heel The foot of the crossing leg is now raised somewhat to avoid undue pressure upon the thigh of the donor leg and immobilized in this position with additional circular plaster bandages connecting the extremities with a figure of eight The position of the legs is reinforced and maintained by a connecting plaster-cast splint, which is rolled together to form a rope and placed upon the two extremities

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Technic (Dickson): A wide, elliptical incision is made around the plantar wart, extending between the webs of both sides of the toe to be

removed and over the dorsum The metatarsal is exposed subperiosteally with reflection of the intrinsic muscles The extensor and flexor tendons are cut, and the metatarsal bone is removed near its base by bone-cutting forceps. The adjoining metatarsals are sutured together with chromic catgut through the capsule of the metatarsophalangeal joints thus obliterating the space made by the removal of the bone followed by closure of the skin

DEFORMITIES

Cicatricial contractures are the common deformities while fascial contractures similar to Dupuytren s contracture of the palmar fascia are rare Cicatricial contractures of the foot are treated similarly to those of the hand (see pp 689 691)

Muscles Tendons Nerves and Vessels

The reconstructive principles are similar to those previously described (Chapter XXIX)

Bones and Joints

DEFECTS

Nonunions of metatarsal and tarsal bones ordinarily do not cause serious discomfort unless accompanied by displacement of the fragments If such is the case operative repair may be warranted The methods of repair are the same as for nonunions of the metacarpal and carpal bones (see p 776)

STATIC DYSFUNCTION AND DEFORMITIES

Hallux Valgus

Hallux valgus or bunion is a lateral deflection deformity of the great toe The deflection causes a protrusion of the head of the first metatarsal bone on the median side of the foot which is covered by a bursa The prominence becomes increased by a median displacement of the first metatarsal bone (metatarsus primus varus) resulting in an abnormal widening of the space between the first and second metatarsal bones This and some separation of the other metatarsals result in splaying of the foot and depression of the anterior arch

From this, it becomes evident that if surgery of hallux valgus deformity becomes necessary surgery alone is not sufficient to relieve all symptoms, unless postoperative measures are taken to overcome the depression of the anterior arch

Of the various reconstructive procedures two are recommended the McBride operation for the average case the Mayo operation for severe

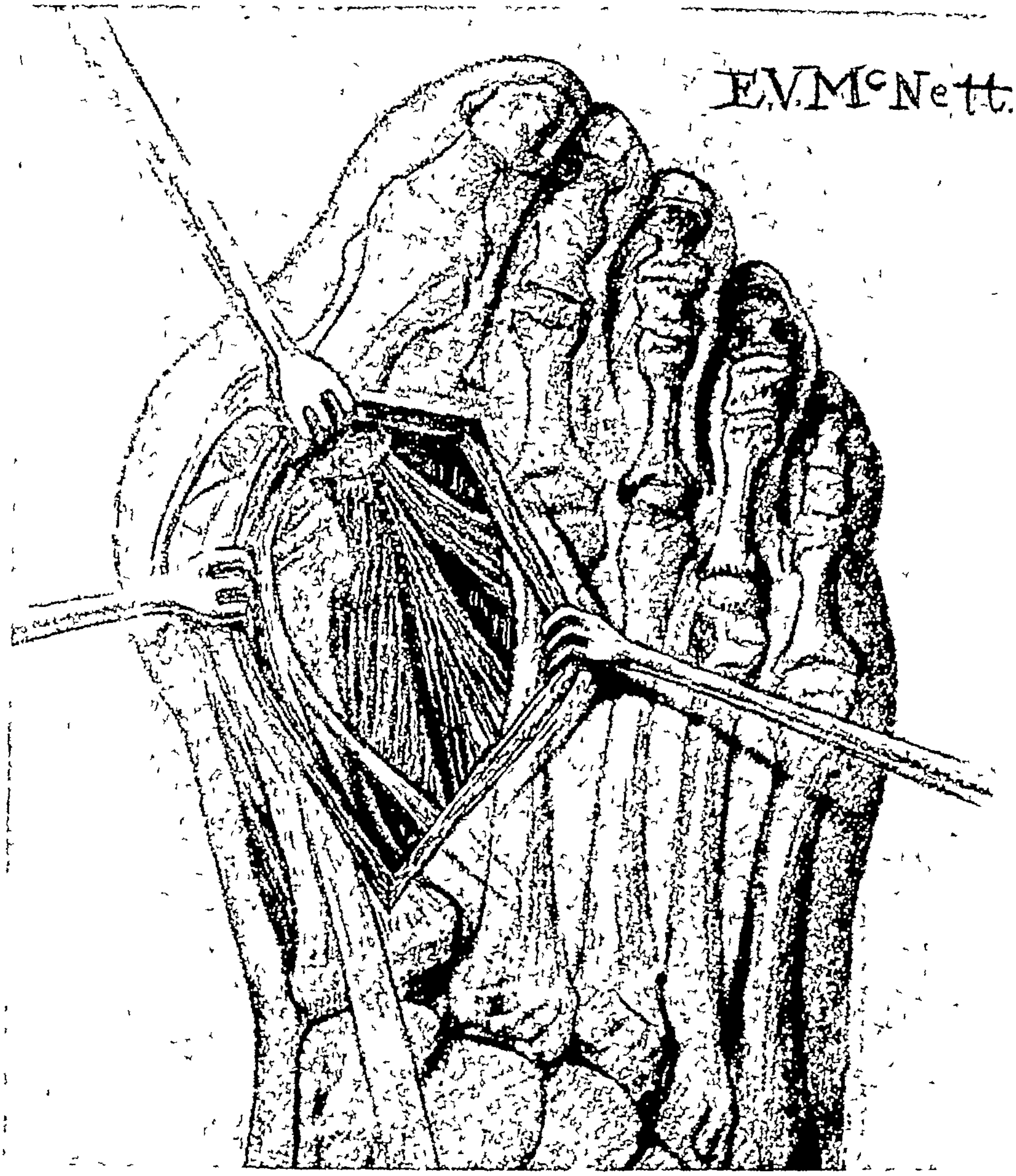

Fig 436 Hallux-valgus operation (McBride) From incision along external border of extensor hallucis longus tendon, lateral aspect of first metatarsophalangeal joint is exposed Flexor hallucis brevis tendon, with lateral sesamoid bone incorporated in its tendon (dotted line), and the two heads of adductor hallucis are seen converging from volar surface to their insertion at base of proximal phalanx of big toe

cases with arthritic changes of the first metatarsophalangeal joint Neither operation, however, seems to be advisable in the so-called "hallux rigidus" with fixed hyperextension of the first metatarsal segment, since many failures have been reported in a large analysis of cases by Bonney and MacNab

The principle of the McBride operation is the transfer of the insertion of the adductor hallucis tendon from the base of the proximal phalanx to the lateral side of the first metatarsal bone, thus relieving the

removed and over the dorsum The metatarsal is exposed subperiosteally with reflection of the intrinsic muscles The extensor and flexor tendons are cut and the metatarsal bone is removed near its base by bone-cutting forceps. The adjoining metatarsals are sutured together with chromic catgut through the capsule of the metatarsophalangeal joints thus obliterating the space made by the removal of the bone, followed by closure of the skin

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care should be taken not to injure the branches of the nervus peroneus profundus, which runs on the lateral side of the great toe The musculus adductor hallucis is severed from its fascial attachment to the base of the proximal phalanx, with careful avoidance of lateral vessels and nerves This muscle has two heads, both must be severed In some cases, the caput transversum of the adductor does not insert with the caput obliquum, but has a separate tendon which runs with the long flexor tendon of the toe, and then swings to the dorsum of the first phalanx.

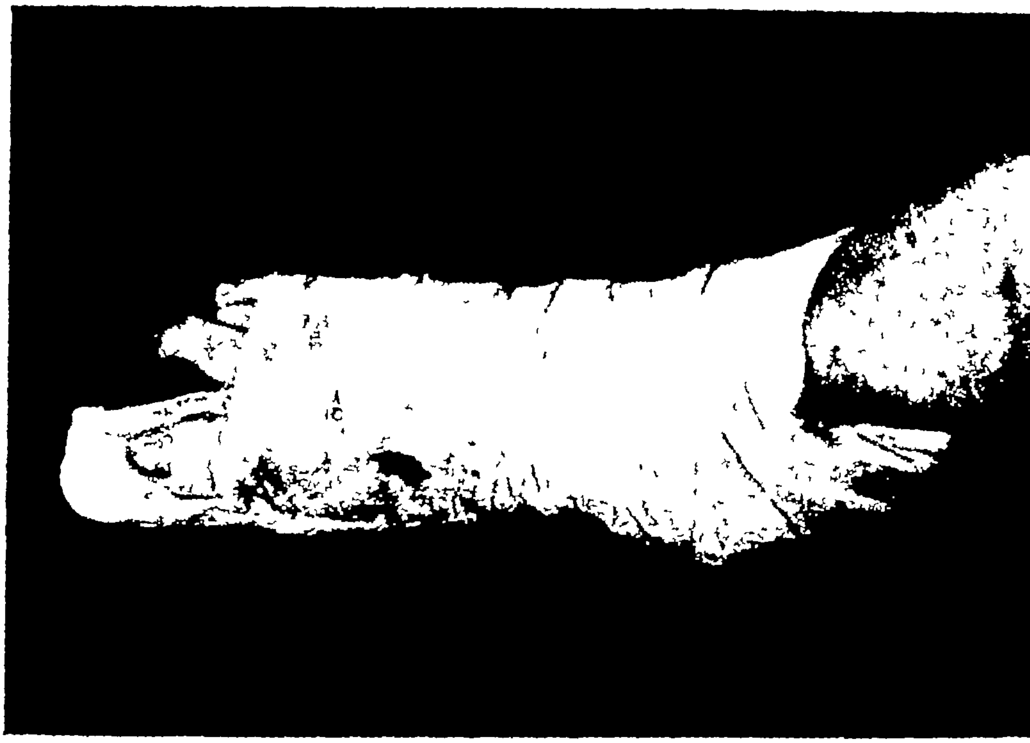


Fig 438 Plantar molded cast "slipper," applied after hallux-valgus operation to hold great toe in abduction and slight flexion

The lateral sesamoid bone is now located within the musculus adductor hallucis and musculus flexor hallucis brevis, and is removed When the sesamoid bone is removed, there remains a large space into which the head of the first metatarsal bone can be squeezed It thus comes to lie close to the second metatarsal bone, improving the anterior arch Now the adductor hallucis tendon is attached laterally to the first metatarsal bone with sutures through the periosteum.

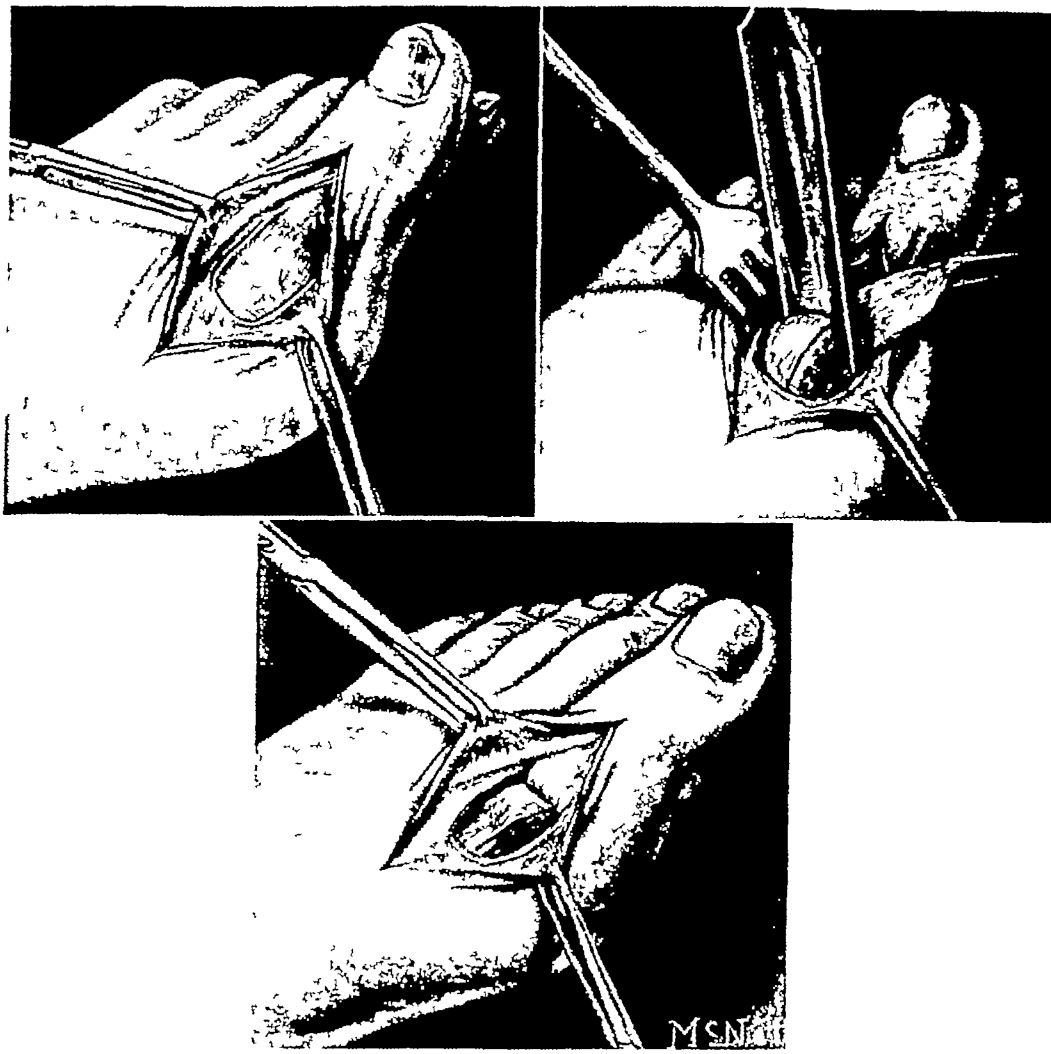
A separate skin incision is now made over the median prominence of the head of the first metatarsal to expose the underlying bursa An incision is made along the dorsal border of the bursa, and the thickened tissue is removed The median prominence of the head of the metatarsal bone is removed vertically with a chisel The thick, fibrous capsule is

Fig. 437: Lateral sesamoid bone is removed. Adductor hallucis is severed from base of proximal phalanx and transferred and attached laterally to head of first metatarsal bone.

lateral deflection of the great toe. This step and the additional one of removal of the lateral sesamoid bone from between the first and second metatarsal bones cause a lateral displacement of the first metatarsal bone —that is a narrowing of the gap between the two bones thus improving the anterior arch

Technic (McBride) (Figs. 436 437) An incision 5 cm (2 inches) long is made starting in the web between the first and second toes extending along the external border of the extensor hallucis longus tendon so as to expose the lateral aspect of the metatarsophalangeal joint Great

a b



c

Fig 439, *a* Hallux-valgus operation (Mayo) From straight incision on median side of metatarsophalangeal joint, U-shaped flap of fascia and bursa is formed, which is pedicled at base of first phalanx.

b. Flap is elevated Exostosis at median surface of metatarsal head has been excised Articular surface of first metatarsal bone is excised, head remodeled

c· Bursal flap is turned into joint space and sutured to lateral capsule of joint

congenital, the majority are due to false statics (association of pes planus, hallux valgus), poliomyelitis, arthritis Mild cases may respond to conservative treatment by means of two adhesive strips· one over the dorsal surface of the proximal phalanx to the sole to overcome its dorsal flexion (hyperextension), and one over the volar surface of the middle phalanx to the dorsum to overcome its volar flexion In advanced cases, surgery is indicated.

Technic (Correction of Hammertoe) (after Stamm) An incision, 2 5 cm (1 inch) long, is made over the interphalangeal joint (if a callus

then sectioned and shortened sufficiently to maintain slight overcorrection of the toe. The wound is closed in layers.

After Treatment A plantar molded plaster-cast slipper is applied and holds the great toe in abduction and slight flexion (Fig 438) After two weeks the splint is removed and weight bearing permitted with the aid of an orthopedic shoe with built-in arch support and metatarsal pad.

McBride and Campbell have reported a median angulation deformity of the great toe following this procedure The cause is an overaction of the unopposed musculus abductor hallucis Campbell advises prophylactic tenotomy of the abductor tendon while McBride overcame the deformity by lengthening the abductor tendon

Technic (Mayo) (Fig 439) The principle of the Mayo operation which is based upon Hueter's excision of the metatarsal head is hemiarthroplasty of the first metatarsophalangeal joint Campbell adds a few good suggestions and describes the procedure as follows

A straight medial incision is made over the inner side of the metatarsophalangeal joint. A U shaped incision is now made through the bursa to form a flap with its attachment on the first phalanx. The inner surface of the flap consists of synovial membrane and is continuous with the interior of the joint. The exostosis or bony hypertrophy on the inner side of the metatarsal head is excised from before backward, flush with the shaft of the metatarsal bone Then about 0 6 cm (¼ inch) of the entire articular surface is excised from the head of the metatarsal bone The head is then remodeled to form a smooth convex surface of the phalanx, thus preserving the entire weight-bearing area of the metatarsal head The bursal flap is then turned into the joint space and sutured to the lateral capsule of the joint by one or two catgut stitches. Thus the bursa is utilized to secure and maintain a movable joint

After Treatment A plantar molded plaster-cast slipper is applied as previously described (Fig 438) After ten days daily foot baths and active exercises are instituted the splint being worn in the meantime. Weight bearing is allowed after two weeks with the aid of an orthopedic shoe with built in arch support and metatarsal pad The abduction splint should be worn at night for several months.

Hammertoe deformity is characterized by flexion of the proximal and often also the terminal interphalangeal joint resulting in a knuckle on which a callus often tends to develop If there is dorsal flexion of the proximal phalanx due to overaction of the extensor or weakness of the flexor muscles the deformity is called clawtoe. One or more toes may be involved The metatarsal heads may be depressed and prominent on the plantar surface causing painful calluses While some of the cases are

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is present the author prefers a transverse elliptical incision with excision of the callus) The extensor tendon is retracted and the interphalangeal joint exposed and with a rongeur the base of the middle phalanx and the head of the proximal phalanx are removed. A hole is now bored down the middle phalanx from its articular surface This hole should be as large as the diameter of the phalanx will allow and about 0 6 cm (1/4 inch) deep The distal end of the proximal phalanx is now shaped to form a peg which will fit into this hole Only the sides and under surface of the phalanx are removed so that the peg is composed mainly of the strong cortical bone on the dorsal surface It is important to keep the sides of the peg parallel otherwise it will tend to slip out of the hole. After suturing the skin a collodion dressing is applied This acts as an efficient splint and should be retained for three weeks If any difficulty is experienced in overcoming dorsiflexion at the metatarsophalangeal joint the extensor tendon should be tenotomized

Technic (Correction of Clawtoe) The flexion deformity of the interphalangeal joint is corrected as just described

The hyperextension of the metatarsophalangeal joint may be overcome by simple lengthening of the extensor tendons and dorsal capsulotomy If the skin of the dorsal surface is too short a Z plastic procedure is added If these procedures do not correct the deformity entirely a resection of the metatarsal head is performed

Lengthening of Extensor Tendons and Dorsal Capsulotomy A longitudinal incision is made over the metatarsophalangeal joints of the involved toe and the long extensor tendon is tenotomized by an oblique incision The dorsal part of the joint capsule which is usually contracted is exposed and excised If several toes are involved the incision is made between the metacarpophalangeal joints from this incision the extensor tendons of two neighbor toes are tenotomized and dorsal capsulotomy of the two joints is performed

Z Plasty If the former procedure is not sufficient to overcome the deformity because of shortening of the skin two additional incisions are added to the longitudinal skin incision to form a Z (see Fig 53 and p 147) The two triangular skin flaps are interchanged thus lengthening the longitudinally contracted skin

Excision of Metatarsal Head If after these two procedures some claw deformity is still left a resection of the metatarsal head with the aid of a costotome will straighten the toe This is particularly advisable in cases where the metatarsal heads are depressed and prominent on the plantar surface causing painful calluses.

Case 1

a

Case 1, *a* Patient, aged sixty-five, with recurrent (colloid) carcinoma of right side of forehead Wide excision of the tumor is marked out A flap containing the temporal vessels to be rotated into the defect is outlined

b Upon operation it was found that the galea aponeurotica was not invaded The tumor was removed with the underlying periosteum and part of the external table The flap was rotated into the defect, care being taken to preserve the periosteum of the donor area A thick split graft was transplanted upon the donor area

c Eight months after the operation No evidence of recurrence of the tumor was noted nine years after the operation

DIVISION FIVE

ILLUSTRATIVE CASES

Case 2 Patient, aged thirty-eight, was working when flash powder exploded Her entire face, both hands, arms, chest, and legs were burned She was treated immediately for shock, and after she had recovered from the latter, the burn areas were treated by washing with soap and water and by application of pressure dressings. The pressure dressings were removed on the twelfth day. After the third-degree burn areas sloughed off, skin-grafting operations were performed to cover the raw areas In thirteen operations, the raw surfaces of face and upper extremities were covered, followed by repair of contractures of both axillas, both elbow joints, both wrists, and the dorsum of the right hand

a In the meantime, ectropion of the right lower lid, severe contracture of the neck, and microstoma had developed The microstoma was of such degree that it was impossible to insert an endotracheal tube for administration of anesthesia Microstoma repaired under local anesthesia

b Two operations were necessary to correct the extensive contracture of the neck. The ectropion of the right lower lid was repaired with a full-thickness graft taken from the supraclavicular region The ectropion of the lip was corrected with a full-thickness graft taken from the abdomen (see also *d, e*) She also had a partial loss of the right ala, which was repaired, according to the method of Fig 170, with a composite graft of full thickness from the anterior part of the helix of the left ear The dotted line indicates the incision around the defect edges The incision is placed so that a small flap is formed to be hinged inward for reception of the graft In *c*, the size of the graft is outlined at the right ear The graft, however, was taken from the left ear, since the left ear was already damaged

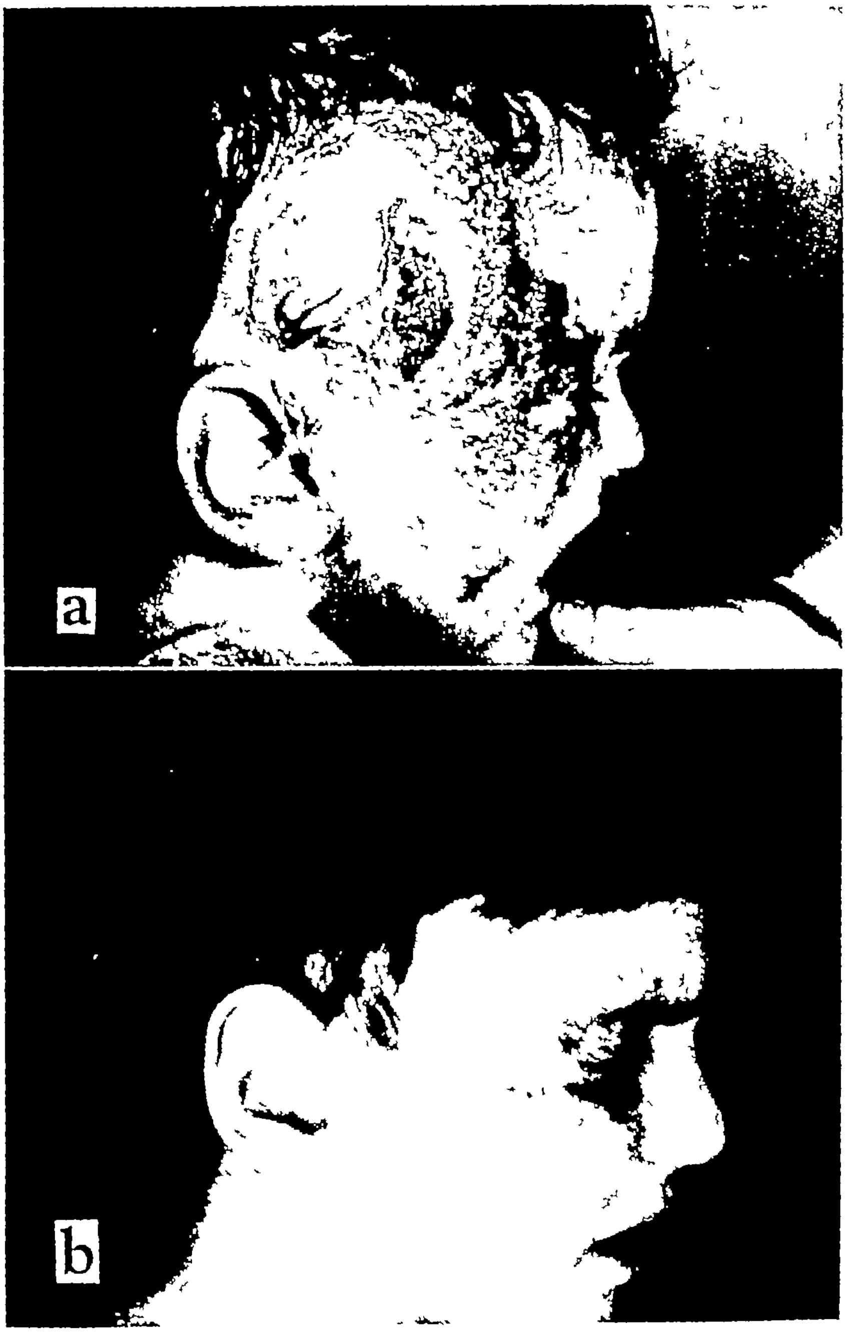
c. After the reconstruction of the ala

d Patient after the finished reconstruction without makeup

e· With makeup


b
c

Case 3



Case 3, *a* Boy, aged four, was struck by an automobile The accident resulted in denudation of the temporal bone and extensive surface defect of the soft tissue of the right side of the forehead

b The exposed bone was covered with a sliding scalp flap which was pedicled in the forehead region The periosteum of the donor area of the flap was covered with a skin graft (compare with Case 8) The surface defect of the temporal area and forehead was covered with thick split grafts Seven years after the operation

Case 2

Case 5

Case 5, *a* Patient, aged sixty-two, had a basal cell carcinoma below the center of the forehead, which was treated with irradiation The tumor recurred ten years later and was then excised and skin grafted After four years the tumor recurred and again was excised The tumor recurred again, the patien was then referred to the author for further treatment A preoperative pictur of the patient is not available The involved area in the middle of the forehea and between the eyebrows is outlined in the diagram Relaxation incision parallel and above the eyebrow for closure of the defect after excision of th lesion are outlined

b Seven months after operation No evidence of recurrence

Case 4

Case 4 *a* Extensive hairy melanoma of forehead including part of the right eyebrow

b The tumor was excised Excision consisted of full thickness of the skin That part of the tumor which involved the right eyebrow was left behind to replace the missing eyebrow Surface defect was covered with a thick split skin graft from the abdomen. Within three months postoperatively the graft changed to a brownish color One year after the operation the surface of the graft was abraded with sand paper for removal of the superficial pigment. Graft has assumed almost normal color since this operation. Two years after the operation

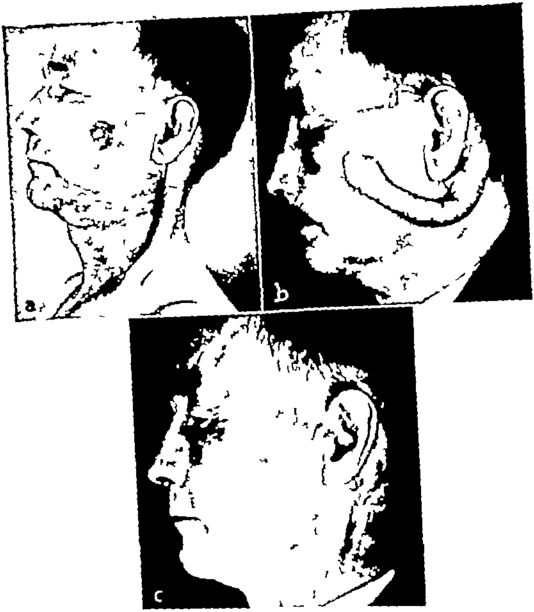
Case 7

a

Case 7, *a* In 1923 patient had 140 "light" treatments, in a beauty parlor, to the tip of the chin for removal of hair Two years before this operation a superficial breakdown appeared in the skin The preoperative microscopic examination of a biopsy taken from the involved part of the chin revealed a fibrosarcoma of the skin The tumor was widely excised including the periosteum of the anterior part of the mandible A relaxation incision in the chin-neck line is marked for the formation of a double pedicle sliding flap

b, c The flap was slid forward to cover the defect at the chin The flap bed in the chin-neck line was skin grafted No evidence of recurrence was noted four years after the operation

Case 6



Case 6 *a* Deep defect of cheek after irradiation of basal-cell cancer. Cervical tube flap prepared.

b Three weeks later the distal pedicle was gradually severed; four weeks later the flap was transferred. The flap was gradually severed from its pedicle two weeks later. This took five days. The flap was then adjusted in place and the pedicle removed.

c Two years after operation. No recurrence after seven years.

Case 8, *a* Boy, aged sixteen, played on the roof of a railroad boxcar, his head came in touch with an overhanging electric wire and 12000 volts went through his body He was unconscious for several days He was treated for shock and severe burns of chest and left thigh Where the scalp came in contact with the wire an area of about 8 7 cm (3½ inches) in diameter was burned full thickness including scalp and skull bone After both had sloughed out (8 months after injury) a scalp flap was elevated In this illustration the head is depicted resting on headrest of the operating table face downward The peripheral end of the flap was near the forehead region, its pedicle at the occiput The periosteum of the flap bed was left behind

b The flap was rotated to cover the exposed dura and the flap bed was covered with one thick split graft taken from the back

c, d The patient developed traumatic epileptic convulsions which occurred as frequently as three times weekly Three months after the transplantation the flap was elevated again and sharp bone edges lying upon the dura were removed All scar tissue between dura and skull edges was excised A bone graft was taken from the median side of the right ilium of the pelvis, and was laid with the periosteal side upon the dura and the prepared bone edges of the skull The bone graft was held in place with two long heavy mattress sutures of silk The flap was then placed over the graft One month later an infection occurred between flap and bone graft which necessitated drainage and removal of the graft Six months later another pelvic bone graft was inserted which healed in and has become fully regenerated The patient had had no convulsions and when seen nine years after the operation was without symptoms.

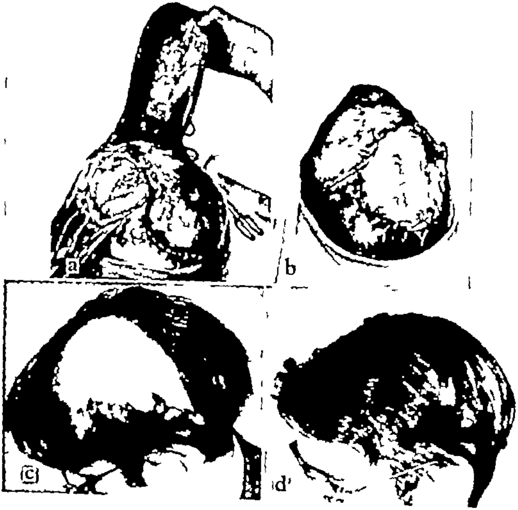

b
c

Case 9

Case 9, *a* Patient, aged eighty-three, with a large horn on the left side of the scalp The history of this formation goes back 15 years when a sebaceous cyst was drained The drainage continued and an ulcer developed The ulcer grew outward and formed this large horn Only after this mass became so heavy that it inconvenienced the patient was an operation considered

b Horn and outer table of skull bone were removed and a thick split graft placed upon the exposed medullary spaces of the bone The graft took well Microscopic examination of the tumor revealed an epidermoid carcinoma The patient died nine years after the operation The operated area remained closed and free of reactivation of the tumor

Case 8



Case 10, *a*, *b* Patient, aged twenty-one, was referred six weeks after her hair had been caught in rollers The accident resulted in a total scalping including total loss of left ear and part of forehead skin After shock treatment, an emergency operation was performed The scalp which had been wrapped in clean linen was shaved and placed upon the skull Some remaining raw areas were skin grafted The scalp graft did not take and only small islands of other grafts remained

c, *d* In four operations the extensive raw surface was covered with split skin grafts The missing left ear was reconstructed with a flap taken from left forearm The flap was tubed at its proximal pedicle and left untubed in its distal part After several delays of transfer of the untubed part an autogenous cartilage graft was shaped and transplanted beneath the flap Circulation of the flap became impaired in this area and part of the cartilage graft became necrotic Four months later the remaining cartilage graft was removed and the flap transplanted to the left mastoid region Eleven days later the flap was severed from the pedicle and after three days adjusted in place Four months later another cartilage graft was transplanted beneath the flap at the mastoid region Nine months later flap and cartilage graft were elevated and raw surface behind the ear was skin grafted Patient wears a wig

Case 9

Case 11

Case 11, *a* Squamous-cell cancer of forehead, treated by irradiation Radio-resistant recurrence after six years The tumor was then excised, exposing the frontal bone

b Formation of tube flap from right side of abdomen Proximal pedicle gradually severed after three months Separation was completed after six days

c Pedicle immediately transplanted to right forearm Gradual separation of distal pedicle was started three weeks later and completed after nine days

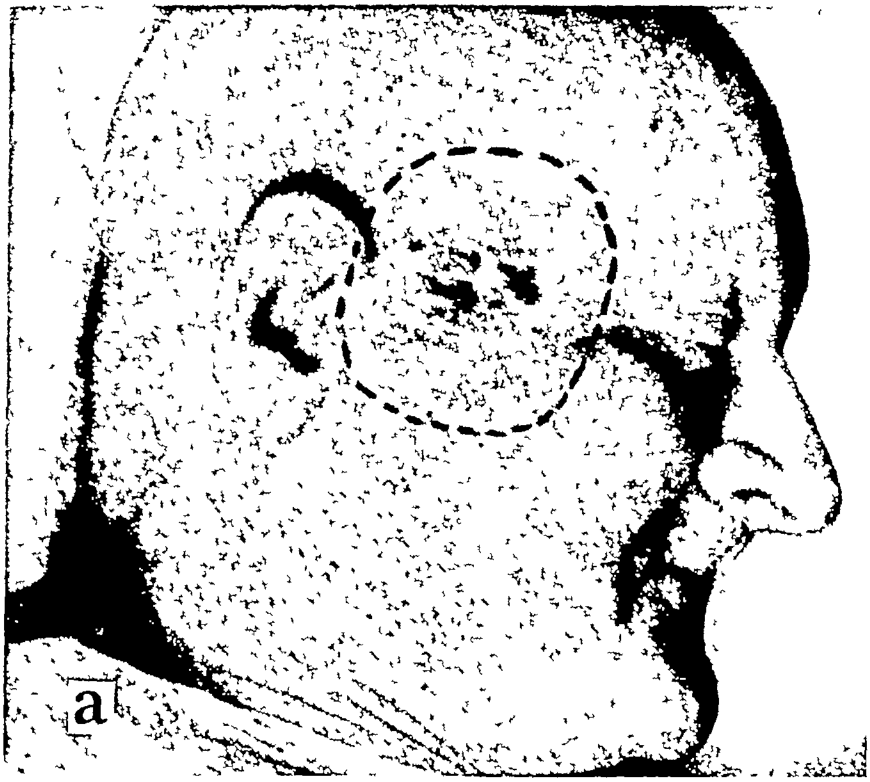
d One month later, arm and flap transferred to forehead The outer table of the frontal bone was removed to permit better adherence of flap to bone Gradual separation of pedicle after two weeks

e Adjustment of flap five days after separation

f One year after operation Patient died four and a half years after the operation from coronary occlusion No evidence of recurrence

Case 10

Case 13



Case 13, *a* Patient, aged sixty-one, with a basal cell carcinoma of the right temporal region which was irradiated After initial healing the skin broke down within the irradiated area The ulcer was approximately 3 cm (1⅕ inches) in diameter Microscopic examination showed ulceration and radiation effect, no tumor cells were visible The area surrounding the ulcer showed typical evidence of x-ray damage The base of the ulcer reached the temporal bone

b The area was widely excised and covered with a thick split skin graft. The upper half of the graft took while the lower half sloughed off An open double pedicle flap was constructed on the median surface of the right upper arm It was elevated in stages and transferred seven weeks later Before the flap was transplanted, the donor area at the arm was skin grafted The arm was fastened to the forehead with adhesive strips Clamping of the pedicle of the flap was begun ten days after the transfer The flap was separated two weeks after the transfer, and adjusted in place ten days later

c Condition eight months after last operation

Case 12

Case 12 *a b* Large depressed scar and partial loss of orbital rim, with displacement of right eyebrow after compound fracture followed by osteomyelitis. The scar was excised. To rotate the lateral half of the eyebrow downward skin and subcutaneous tissue of forehead and scalp were widely mobilized from a long sagittal incision. A fascia lata fat graft was transplanted into the depressed area and the wound edges were sutured together in layers.

c Eight months after operation *d* Six years after operation

Case 14, *a* Patient, aged forty-six, referred for closure of full-thickness defect of left cheek after irradiation for cancer Frequent biopsies were negative A cervical tube flap was constructed, reaching from the left mastoid process to the clavicle Three weeks later, the flap was lengthened This part of the flap was left untubed and returned to its original site Two weeks later, it was elevated again, the peripheral pedicle narrowed from each side, and a laboratory clamp attached to the remainder of the pedicle The pedicle was gradually crushed within five days

b: Four weeks later, the peripheral half of the untubed part was raised and lined by folding it upon itself The flap bed was skin-grafted Two weeks later, the entire untubed part of the flap was raised, it became cyanotic, and hence was returned to its original site

d One week later, the communication of covering and lining of flap—that is, the peripheral edge of the flap—was incised

e· One week later, the defect edges of the cheek were denuded and freed of all scar tissue The flap was transferred and sutured in place Ten days later, the pedicle was gradually crushed with a laboratory clamp This took four days, after which the flap could be severed from the pedicle and adjusted in place Five months after last stage (From H May Surgery)

Case 13

Case 15, *a*: Facial palsy on right side after fracture of skull Conservative treatment over a period of eight months was unsuccessful Repair of the deformity by suspension of the paralyzed muscles with fascial grafts, one loop to upper lip, one loop around right commissure of mouth, one single strip to lower lid (see Fig 58, p 174)

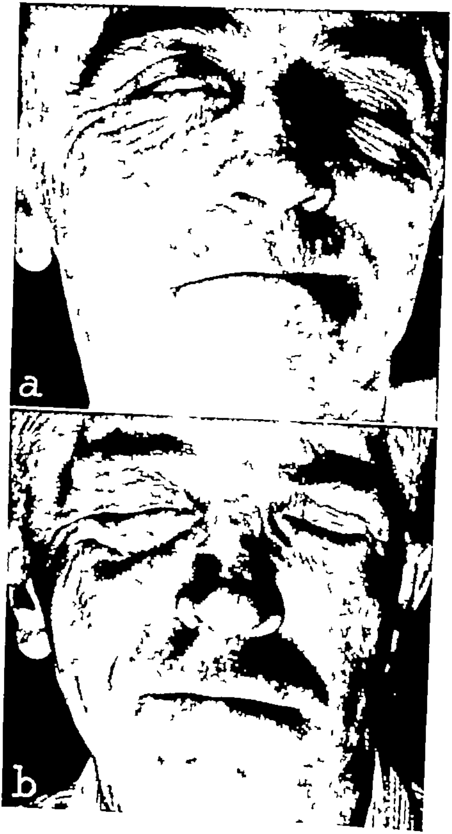
b: Four months after operation

Case 14

Case 16, *a* Patient, aged twenty-two, gave the following history Ten years previously a left lower molar tooth was removed under local injection with novocaine A few hours later the anesthetic field was still present at left side of the cheek which began to look whitish Gradually the left cheek wasted away A few years later a whitish area appeared at the left side of her forehead and there again was wasting of tissue Finally, she developed a typical picture of hemiatrophy of the left side of the face

b From incisions below the left side of the mandible dermal grafts which were doubled were inserted into the hemiatrophic pockets About two weeks after the operation the cheek swelled up and aspiration revealed serum This illustration depicts the patient eleven months after the operation

Case 15

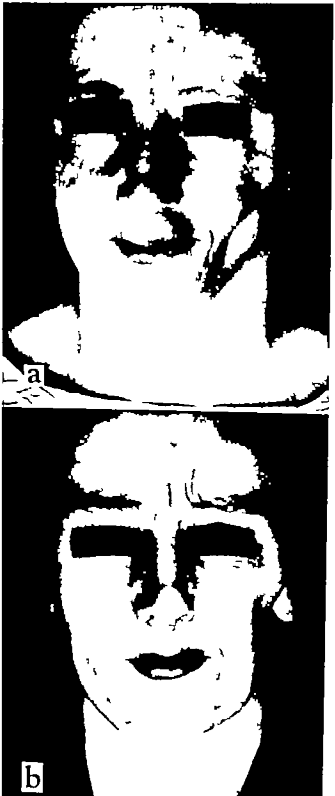


Case 19

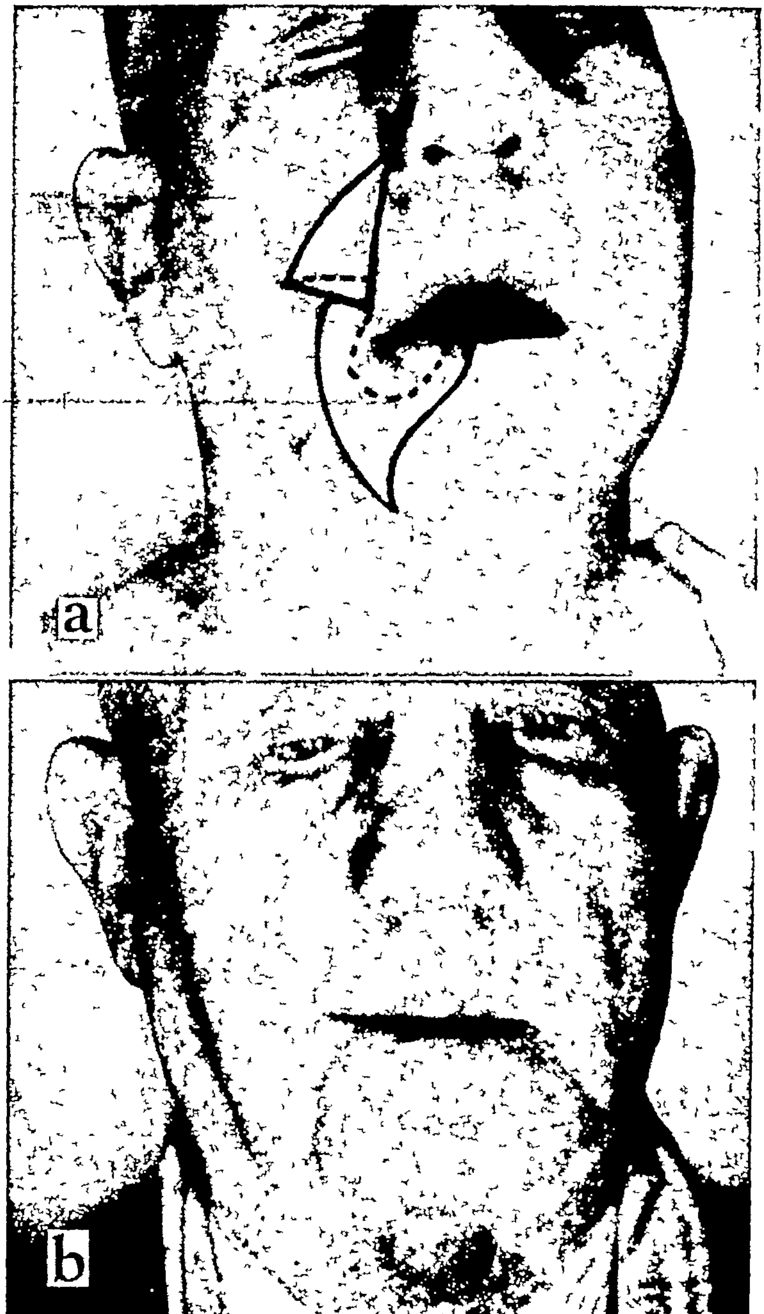
Case 19, *a* Patient, aged seven, with a large hypertrophic scar of right side of face after second degree of burn, contracting mouth

b The entire scar was excised including right half of upper and lower lip and a thick split graft was transplanted from the upper half of the chest The ear was reconstructed twelve years after the accident

Case 16



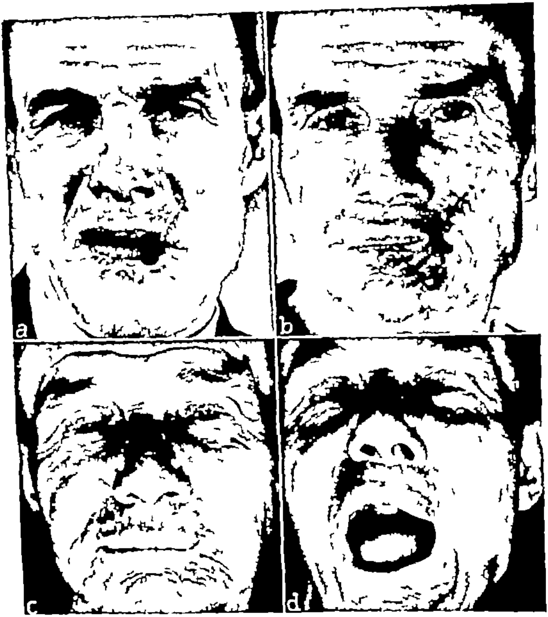
Case 22



Case 22, *a* Patient, aged seventy, with a squamous-cell carcinoma at right side of lower lip near the commissure No evidence of metastasis Involved areas are outlined with dotted lines Heart-shaped excision and excision of triangle in right nasolabial fold for closure of the defect with Burow method is outlined

b Six months after operation

Case 20

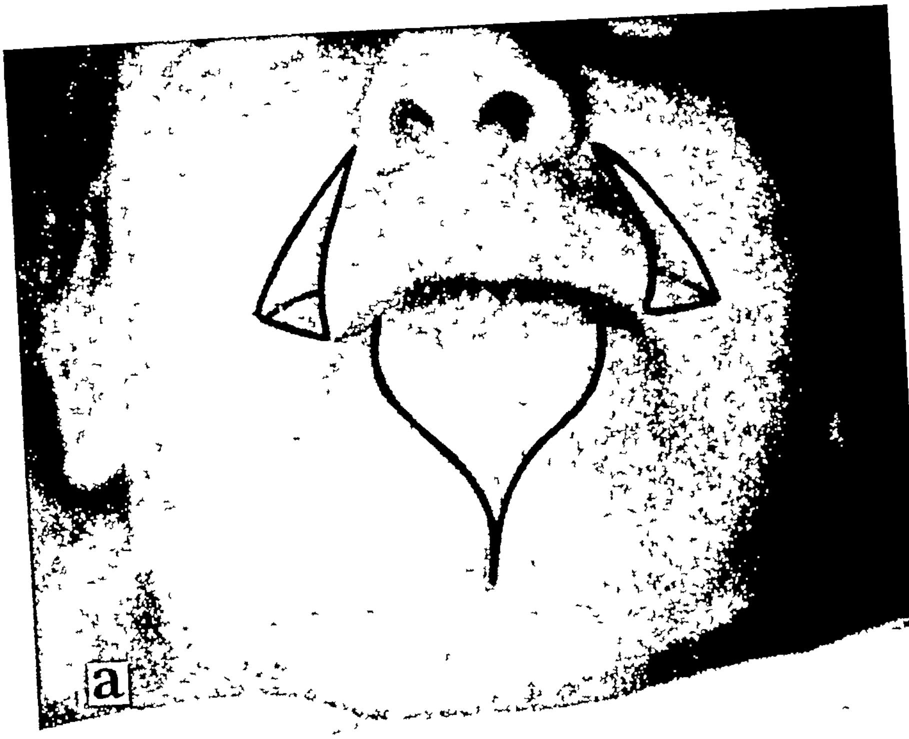


Case 20 *a* Small cornifying squamous-cell cancer of lower lip. Excision at lower lip and flap at upper lip marked. The width of the flap is only one half of that of the defect in order to shorten upper and lower lip proportionately

b After rotation of the flap the left commissure of the mouth is preserved the pedicle of the flap crosses the mouth

c d Three months afteer separation of the pedicle

Case 24

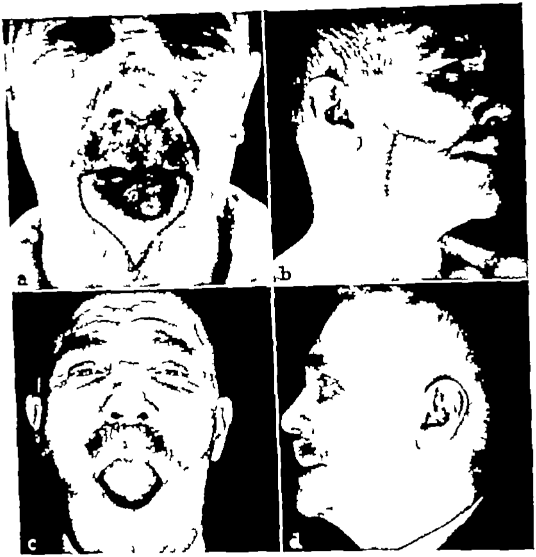


Case 24, *a* Patient, aged forty-eight, with extensive hemangioma of lower lip Heart-shaped excision of full thickness of lip and chin is outlined Two triangles to be excised from the nasolabial region are also outlined for closure after the Burow technic Dotted lines indicate mucous membrane triangles for formation of vermilion border of commissures

b After excision of tumor and nasolabial triangles Note everted mucous membrane triangle on right side

c Three months after operation

Case 23

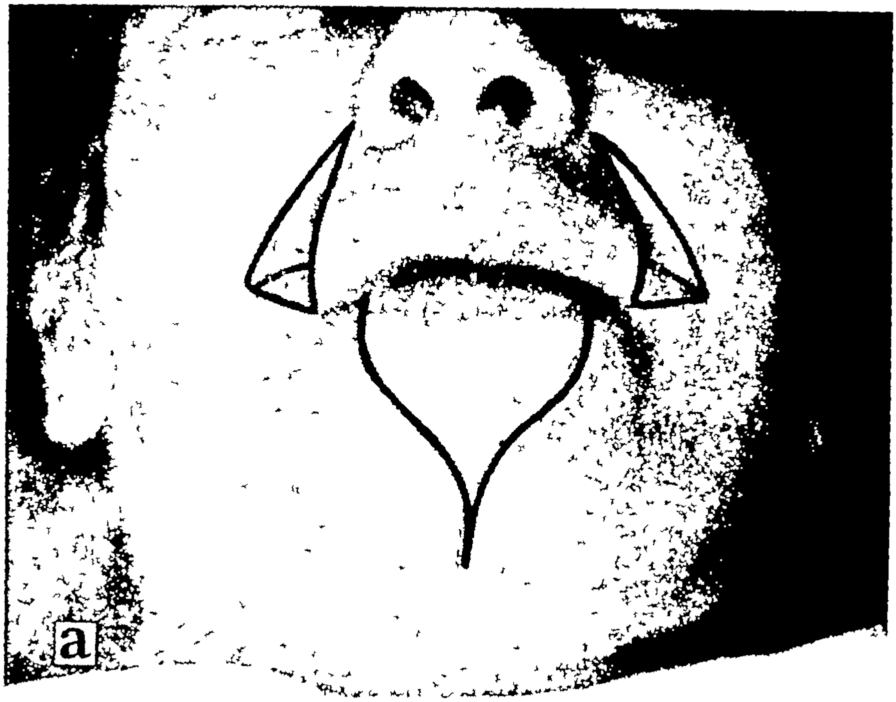


Case 23 *a* Patient with large squamous-cell carcinoma of lower lip—no evidence of metastasis. Line of heart shaped excision outlined. Operation according to Dieffenbach s method

b Same patient five days after operation Was discharged twelve days after operation

c Same patient thirteen months after operation No evidence of recurrence after seven years. (H May Surg., Gynec. & Obst.)

Case 24



Case 24, *a* Patient, aged forty-eight, with extensive hemangioma of lower lip Heart-shaped excision of full thickness of lip and chin is outlined Two triangles to be excised from the nasolabial region are also outlined for closure after the Burow technic Dotted lines indicate mucous membrane triangles for formation of vermilion border of commissures

b After excision of tumor and nasolabial triangles Note everted mucous membrane triangle on right side

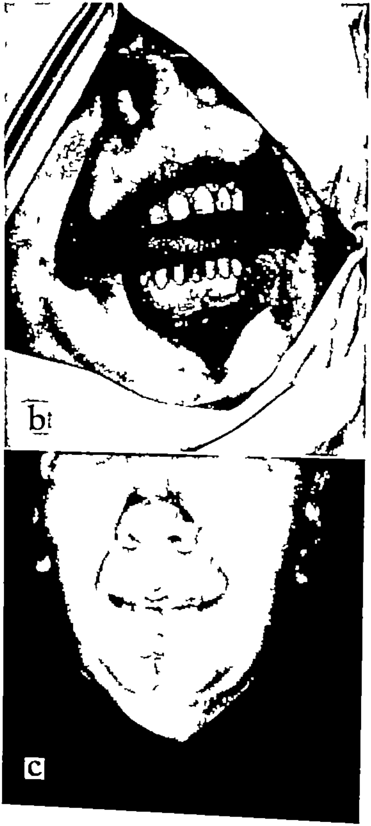
c Three months after operation

Case 24

Case 25, *a* Patient, aged sixty-two, had squamous-cell carcinoma, Grade II, of the lower lip, which had been treated elsewhere, first, by cauterization, later, by radiation Nine months later, he was referred to the author for closure of the extensive defect, which included part of the mandible All areas looked free of tumor, with exception of a suspected area at the bottom of the defect, but this proved to be negative by microscopic examination There was, however, one enlarged lymph node, palpable beneath the right side of the mandible, and was freely movable Hence, it was planned to perform a radical neck dissection The defect's edges of soft tissue and mandible showed evidence of extensive x-ray necrosis, hence, the defect had to be enlarged until normal tissue was encountered The shape of the defect is depicted by the heart-shaped outline of excision The defect was closed according to the method shown in Fig 72, p 205

b–d Patient made an uneventful recovery He was discharged from the hospital on the eighth postoperative day All wounds had healed These photographs were taken eighteen days after the operation Twenty-one days after the operation, the submental and right submandibular glands were removed by radical dissection, as well as the right cervical glands after removal of the right sternocleidomastoid muscle and the right internal jugular vein Patient had an uneventful recovery, and was discharged six days after the operation No evidence of reactivation of tumors after 9 years

Case 24

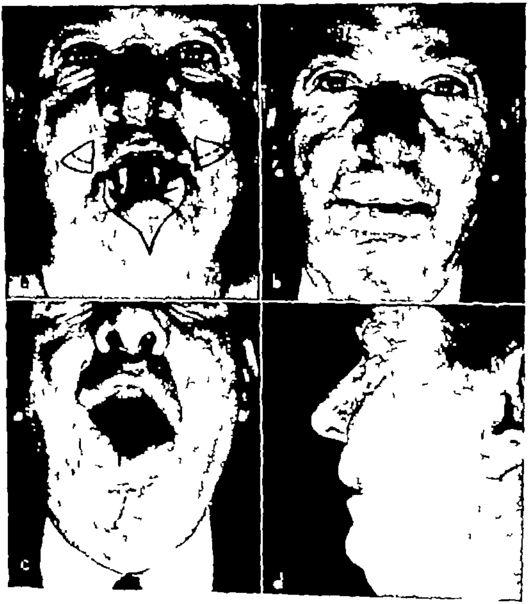


Case 26

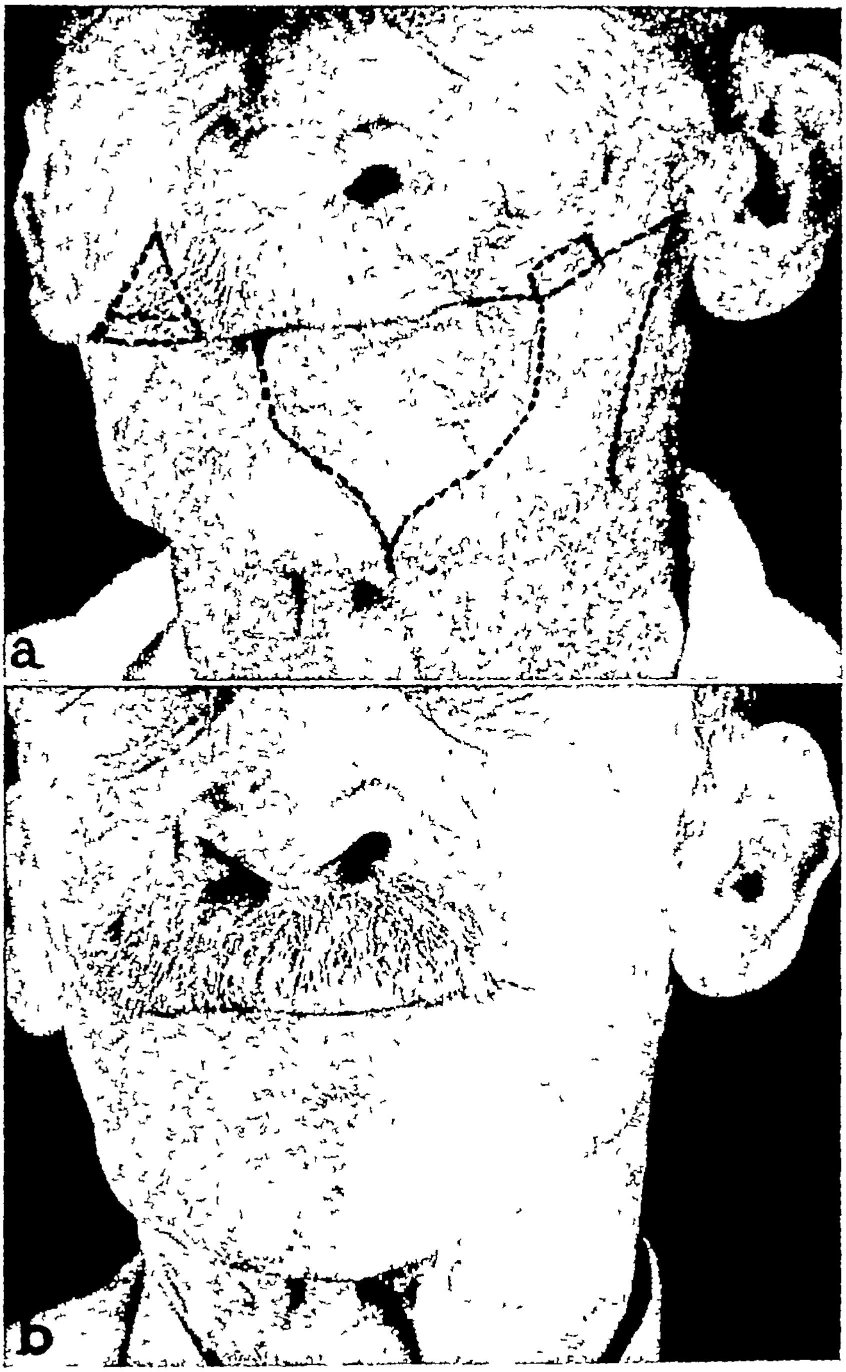
Case 26, *a* Patient, aged forty-eight, with basal cell carcinoma of left commissure of mouth The involved area is outlined by dotted lines Heart-shaped excision of lower lip and chin and excision of triangle from upper lip is marked out, together with the Dieffenbach flap for closure of the defect

b, c Four years after the operation there was no evidence of reactivation

Case 25



Case 27



Case 27, *a* Squamous-cell cancer of lower lip had been unsuccessfully treated with excision and Estlander rotation flap from upper lip Hence a more radical operation was performed, Dieffenbach's method on same side and Burrow's method on other side

b Same patient ten months after operation He died from metastases twenty months after operation

Case 26

Case 29, *a* Patient, aged sixty years, with squamous-cell cancer involving almost the entire lower lip, the left angle of the mouth, and the left fourth of upper lip Owing to extent of the lesion, radiation was contraindicated There was no evidence of metastasis The lines of excision are outlined

b After excision of the diseased tissues

c The defect was closed with a bilateral composite cheek flap according to the method shown in Fig 74 Formation and mobilization of the left composite cheek flap. The defect of the upper lip was closed by simple skin-sliding The patient was discharged from the hospital two weeks after the operation

d, e. Five months after operation No reactivation or metastasis nine years after operation

Case 28

Case 28 *a* Patient aged fifty two, had a basal cell carcinoma of center part of upper lip which was excised The defect was closed with an Estlander Abbé flap from the lower lip The tumor however recurred. It was then widely excised and a turnover flap was prepared from the right side for closure of the upper lip after the Ferris Smith method.

b After elevation of the turnover flap the flap was depilated and turned over to form the lining of the upper lip. A cheek flap from the right side was rotated to form the outside. An oral mucous membrane flap was rotated to resurface the raw surface of the turnover flap and to form the vermilion border There was no recurrence of the tumor two years after the operation

Case 30, *a* Cicatricial deformity of upper lip after destruction of a cavernous hemangioma, remnants of another hemangioma at left cheek

b The cavernoma at the cheek has been injected with alcohol and removed twenty-four hours later after ligation of the arteria maxillaris externa and vena maxillaris externa, two weeks later, removal of the scars of the entire upper lip, leaving the mucous-membrane lining and parts of the vermilion behind, closure of the defect with a scalp flap containing the right arteria temporalis

c. Severance and return of pedicle after ten days, adjustment of flap several days later (Case of E Lexer)

Case 29

Case 31

Case 31, *a* Complete cleft lip and cleft of alveolar process Operation seven weeks after birth

b Eighteen months after operation

Case 30

Case 33

Case 33, *a* Through and through left-sided cleft lip and palate Closure of cleft of lip, formation of nostril, and bridging of the cleft in the alveolar processi when child was five weeks of age Axhausen-LeMesurier technic Closure of cleft of palate at the age of two years

b Eight years later

Case 32

Case 32 *a b* Extensive through and through cleft lip and palate. Closure of lip cleft formation of nostril and bridging of the cleft in the alveolar process when child was six weeks of age. Axhausen LeMesurier technic. Closure of palatal cleft at the age of two years.

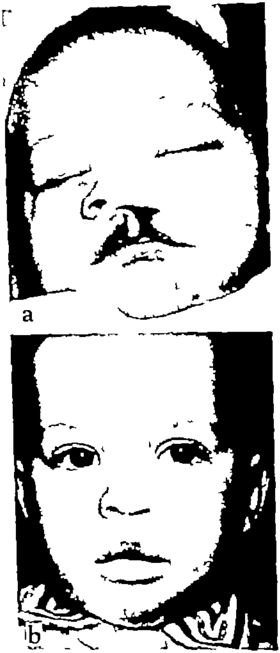
Case 35

Case 35, *a* Patient, aged seventeen, born with bilateral cleft lip and palate Father would not give permission for operation in spite of numerous pleas from his family, friends, neighbors, and in spite of the fact he had to present his case once before court At this age he reluctantly gave permission for surgical repair

b, c Closure of the bilateral lip defect in one stage

d, e Columella was elongated in stages by use of skin of the prelabium and closure of the resulting surface defect of the premaxilla with a full-thickness graft Protruding premaxilla removed, missing teeth replaced with prosthesis which also had an appliance to hold the upper lip in normal protrusion

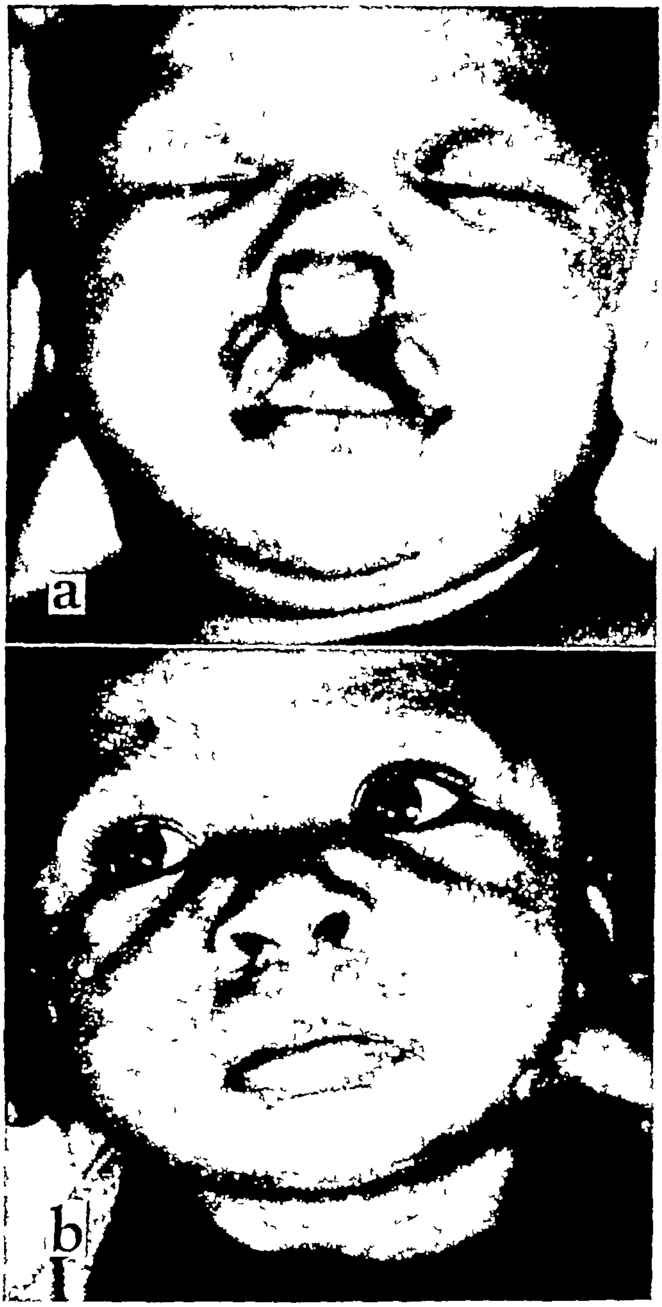
Case 34



Case 34 *a* Through and through cleft lip and palate. Closure of the cleft of lip, formation of nostril and bridging of cleft in alveolar process when child was six weeks of age. Axhausen LeMesurier technic. Closure of cleft of palate two years later.

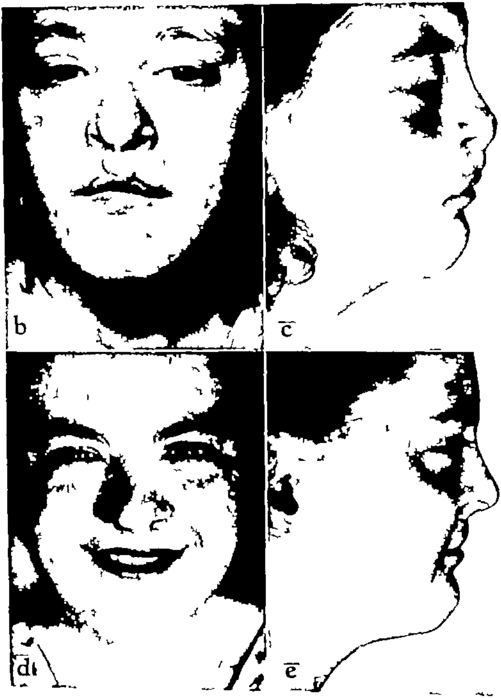
b Three years later.

Case 36



Case 36, *a, b* Bilateral cleft lip and cleft in anterior part of palate Both were closed when child was four weeks of age

Case 35



Case 38

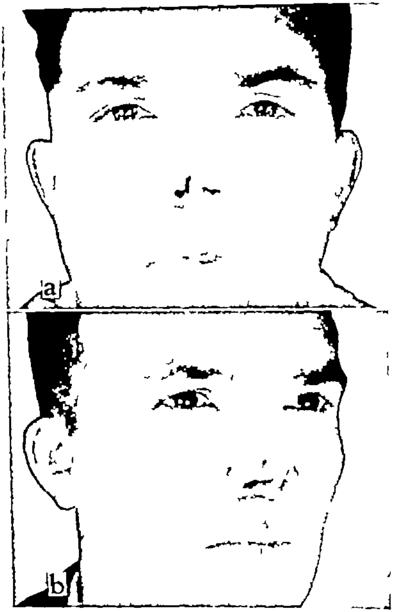
a

Case 38, *a* Patient, aged sixty-two, was treated 40 years ago with paraffin injection to elevate a traumatic flatness of the ridge of the nose The cosmetic result was good and the patient had no symptoms until one summer when she exposed her nose to an extensive sunburn, the paraffin melted, the skin broke down and the cartilages were exposed The entire damaged area was removed by excision leaving a full-thickness defect which was closed with a forehead flap

b Five weeks after transfer of forehead flap the pedicle was severed and flap and pedicle were adjusted

c Six months later the rather thick flap was defatted

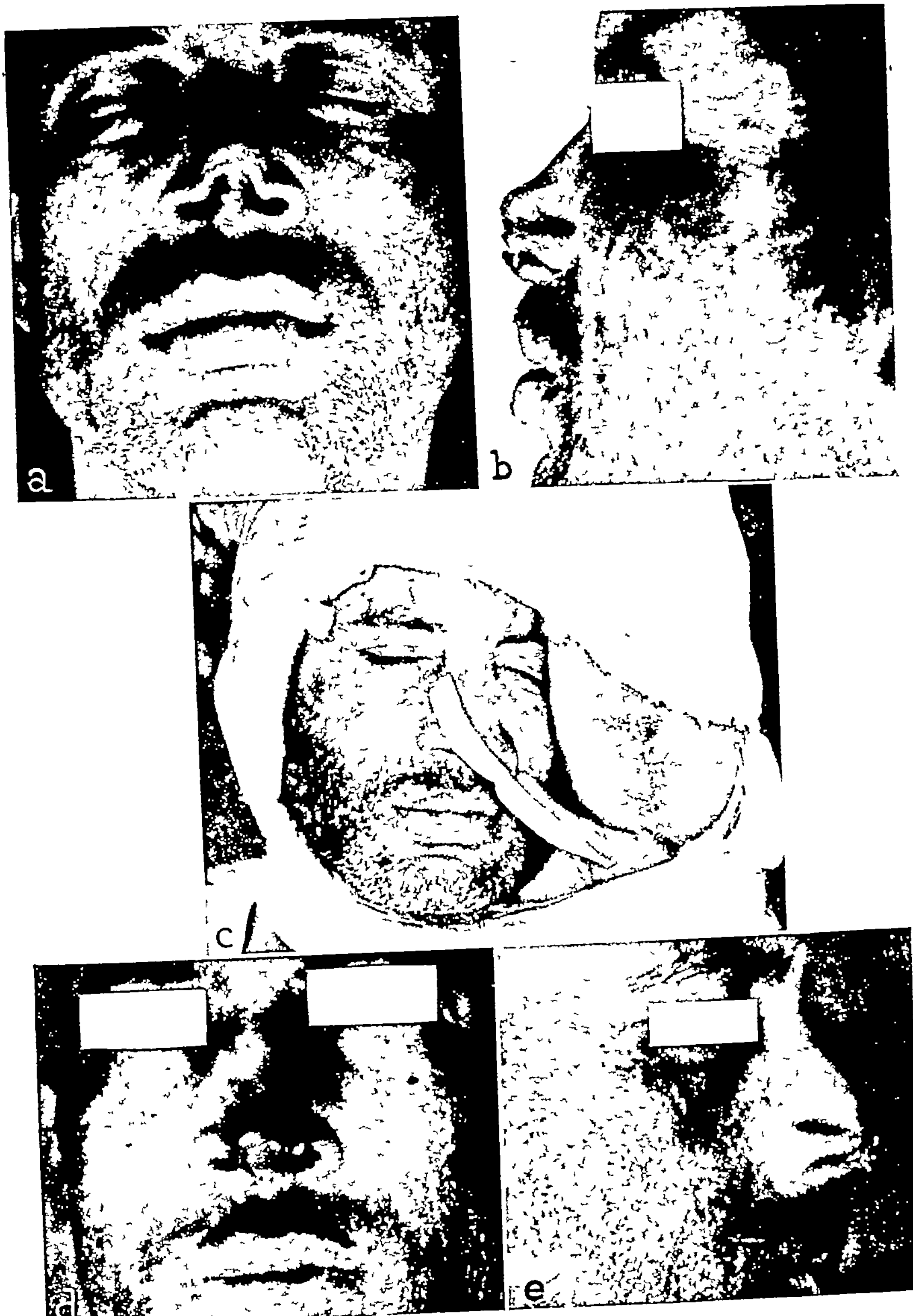
Case 37



Case 37 *a* Patient aged twenty-seven with traumatic loss of tip of nose and columella-alar angle on right side. Immediately after admission a skin graft was applied to the tip of the nose and lacerations of the upper lip were repaired He was referred to the author six weeks later

b The defect at the columella alar angle was closed with a composite skin cartilage graft (see page 295) which was taken from the rim of the right ear The defect at the ear was closed according to the method of Fig 239 This picture depicts the patient four weeks after the operation

Case 39



Case 39 Defect of tip of nose, nose, and parts of alae and columella from human bite, reconstructed with tube flap from arm

Case 38

Case 41 Patient, aged sixty-four, had had basal-cell cancer of the right side of the nose for sixteen years He had had a full course of x-ray radiation (3000 R from sides, 3000 R from front, unfiltered) The lesion had continued to advance, and involved the tip of the nose Radical excision of the right ala, parts of the tip of the nose, and parts of the right lateral wall of the nose was performed No evidence of recurrence The defect was closed with a lined sickel flap from the scalp, which was developed in several stages, according to the method of Fig 172, p 299 The first mobilization consisted in elevation of the scalp flap between temple and frontal pedicle

a Four weeks later, the flap was mobilized again between the two pedicles, and the frontal pedicle was severed Four weeks later, the frontal part of the flap was elevated and lined with a composite graft consisting of skin and cartilage The latter was taken from the anterior surface of the concha of the right ear The raw surface of the concha was covered with a thick split graft The pedicle was returned Both grafts took completely.

b Two weeks later, transplantation of the flap from the forehead to the nasal defect The borders of the defect were circumscribed with an incision and hinged inward, to increase the raw surface and to provide a broader base for the flap Forehead area was covered with a full-thickness graft taken from the right supraclavicular region The wound edges of the flap bed were held together with mattress sutures, which were tied over bismuth tribromophenate (xeroform) gauze One week later, partial separation of the pedicle Five days later, the pedicle was severed entirely, followed two days later by replacement of the pedicle to the flap bed on the skull and adjustment of the flap to the nasal defect edges

c Two months after the last stage

Case 40

Case 40 *a b* Traumatic left-sided deviation of nose. Impairment of breathing from marked right-sided deviation of septum while the free edge of the septal cartilage was found deviated in the left nostril.

c d After rhinoplasty which consisted of slight reduction of the osseous ridge of the nose greater reduction was made on elongated right side than on left side Both anterior processi of maxilla were severed and both nasal bones shifted into midline Removal of the deviated free end of the cartilaginous septum. The impairment of breathing remained Patient may need submucous resection in the future

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c Two months after the last stage

Case 41

Case 42

Case 42, *a* Girl, aged nineteen, with partial loss of upper lip and nose from an automobile accident The upper jaw was fractured in four places and severed through the sinuses The mandible was fractured in two places Emergency treatment was performed elsewhere consisting of arresting hemorrhage mainly by pulling the facial wound edges together with thick silk sutures, tracheotomy, and shock treatment

b After transfer of the patient (ten days after the accident) the facial wounds were separated and reduction and fixation of the maxillary fragments with the arch wire method and suspension of the maxilla was carried out (see page 433 and Fig 260) The fractures of the mandible were stabilized with intramedullary Kirschner wires Three weeks later the missing part of the right side of the upper lip was replaced with a flap from the lower lip by the Estlander-Abbé method Six weeks later a forehead sickle flap, pedicled in the left temporal-mastoid area, was elevated in preparation for reconstruction of the nose In the first stage the flap was elevated between two pedicles and returned Two weeks later the peripheral pedicle over the eyebrows was severed, three weeks later the entire flap was elevated and returned

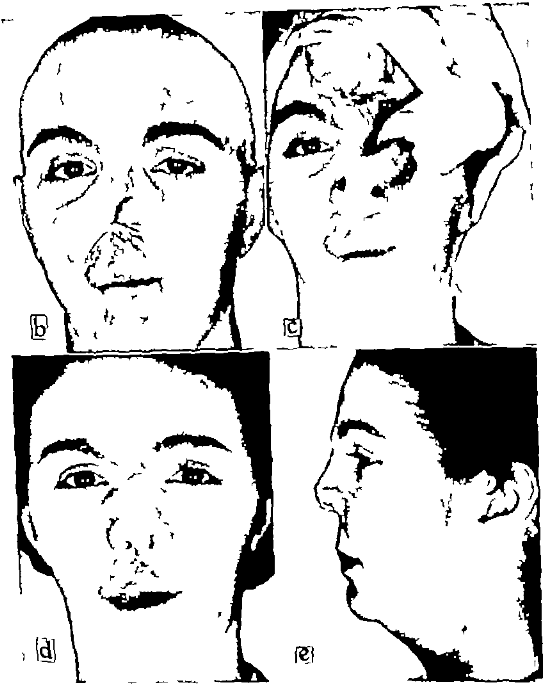
c After all edema in the flap had subsided, i e two months after the last stage, the flap was raised, the peripheral end folded to shape the nose and the remainder of the flap tubed The donor area at the forehead was covered with a thick split skin graft The scalp wound edges were held together with heavy mattress sutures Three and one-half weeks later the flap was incised above the nose and a laboratory clamp applied for gradual crushing of the pedicle Three days later the flap was severed and the pedicle returned to the skull One week later the nose flap was adjusted

Case 41

Case 43, *a, b* Nasal deformity mainly consisting of bulbous tip, enlargement of the lower lateral cartilages, and hanging columella

c, d From a Réthi incision the lower lateral cartilages were reduced in height as well as in width The columella cartilages were reduced in height The upper lateral cartilages were reduced in width The hanging of the columella was overcome by excision of a strip of free edge of the cartilaginous septum and reduction of the columellar cartilages

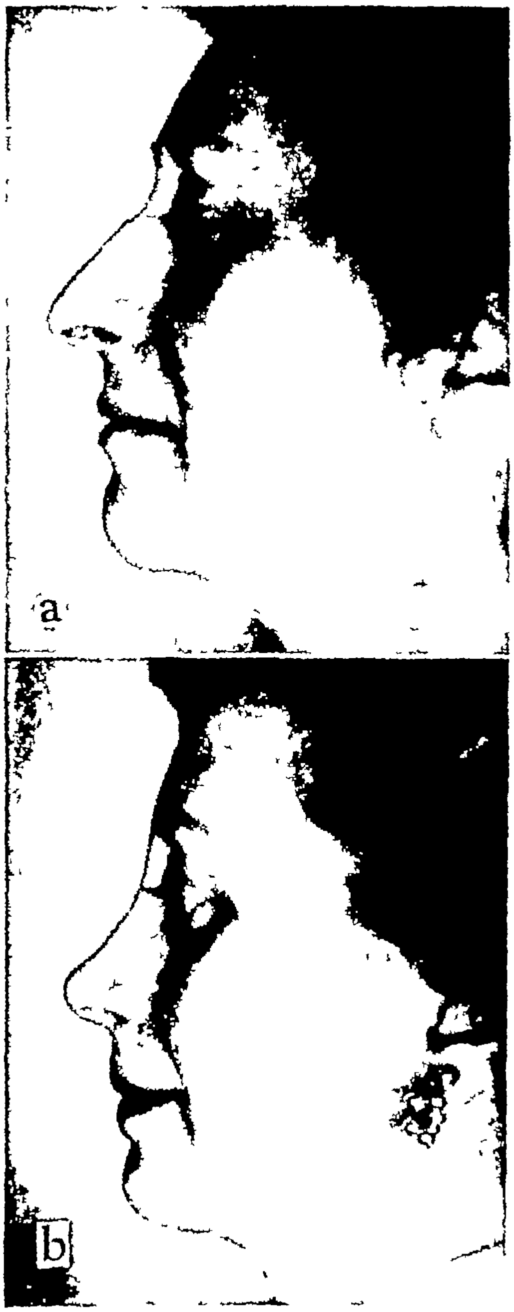
Case 42



d e It took several readjustments of the nose flap to give the nose the final shape and to open the nostrils. Four months later an autogenous rib cartilage graft was inserted to hold the ridge of the nose elevated

All of patient's scars (face arms tracheotomy scars) became hypertrophic. Irradiation smoothed out all but those of upper lip which can be disguised to certain degree with make-up

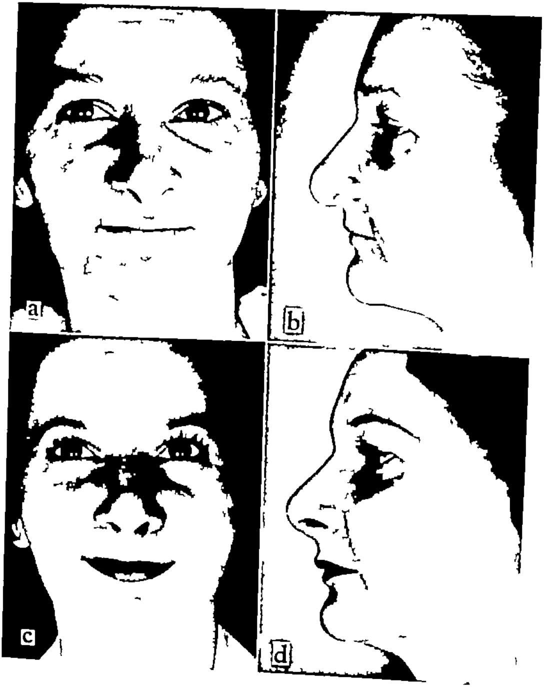
Case 44



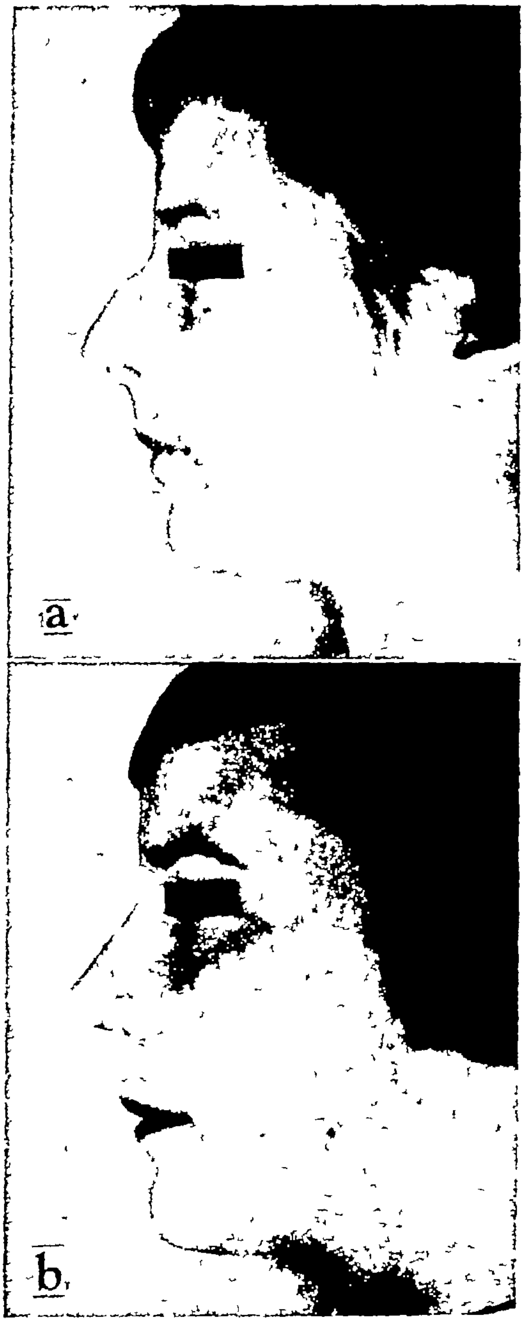
Case 44, *a* Hump nose Long nose

b Rhinoplasty consisting of reduction of the nose in height as *well* as in length

Case 43

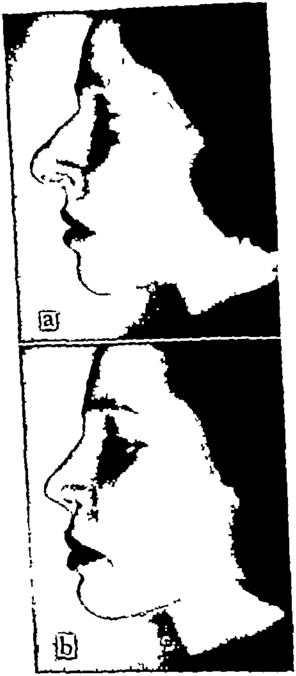


Case 46



Case 46, *a* Patient, aged fifteen years, with marked hump nose
b After reduction of nose in height and in length

Case 45



Case 15 *a* Long large nose Drooping columella
b Correction of the nasal deformity by reduction of the nose in height and length.

Case 48

Case 48, *a* and *c* Patient aged sixty-three, with a rhinophyma of many years' duration

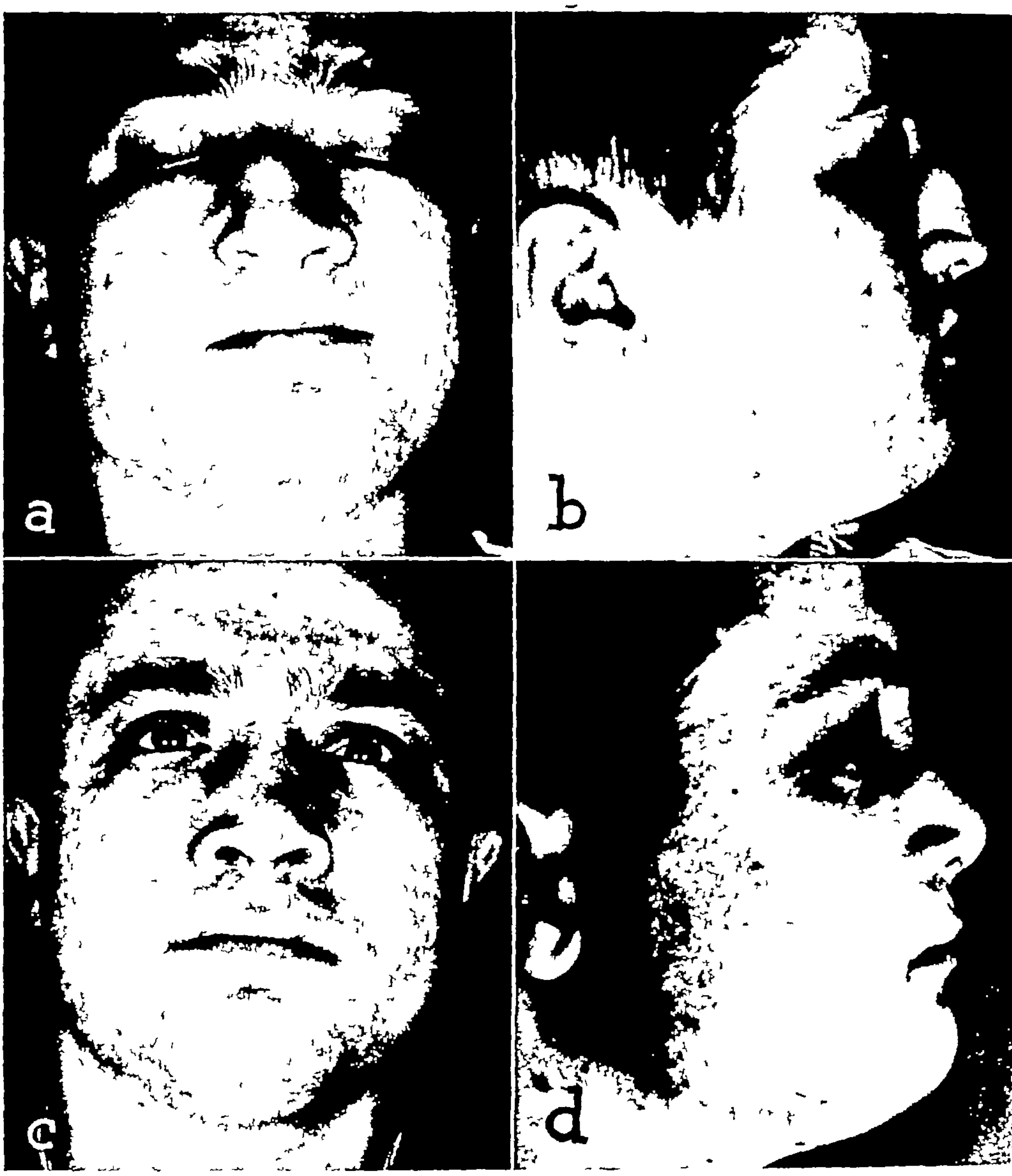
b and *d* Entire skin of the nose containing the rhinophyma was removed and replaced with a thick split skin graft from the upper part of the chest The dressing was changed ten days later and there appeared a rent in the left columella-alar angle Two months later this defect was closed with a composite skin cartilage graft from the right ear (compare with Case 37, p 897)

Case 47

Case 47 *a* Marked enlargement of nose in height as well as in length Note narrow upper lip.

b After rhinoplasty which consisted of marked reduction of all parts of the nose. Upper lip has become longer from shortening of nose and reduction of the crest of the tuberculum maxillae.

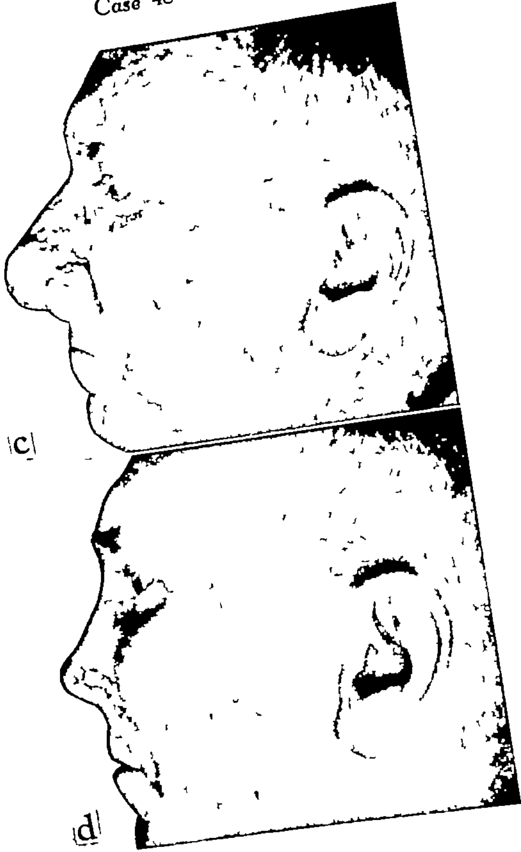
Case 49



Case 49, *a, b* Patient, aged twenty, with traumatic deformities of nose deviation of nose, hump formation, shallow depression of cartilaginous ridge, wide nasal tip, wide nostrils, and marked deviation of septum causing impaired nasal breathing

c, d After removal of the hump, severance of the anterior processi of the maxilla, shifting the nasal pyramid toward the left, reduction of width of tip, reflection of the median part of these cartilages toward the midline and suturing them back-to-back to fill out the slight depression of the cartilaginous ridge Reduction of width of nostrils, submucous resection, and severance of the septum from its base and shifting the septum into the midline

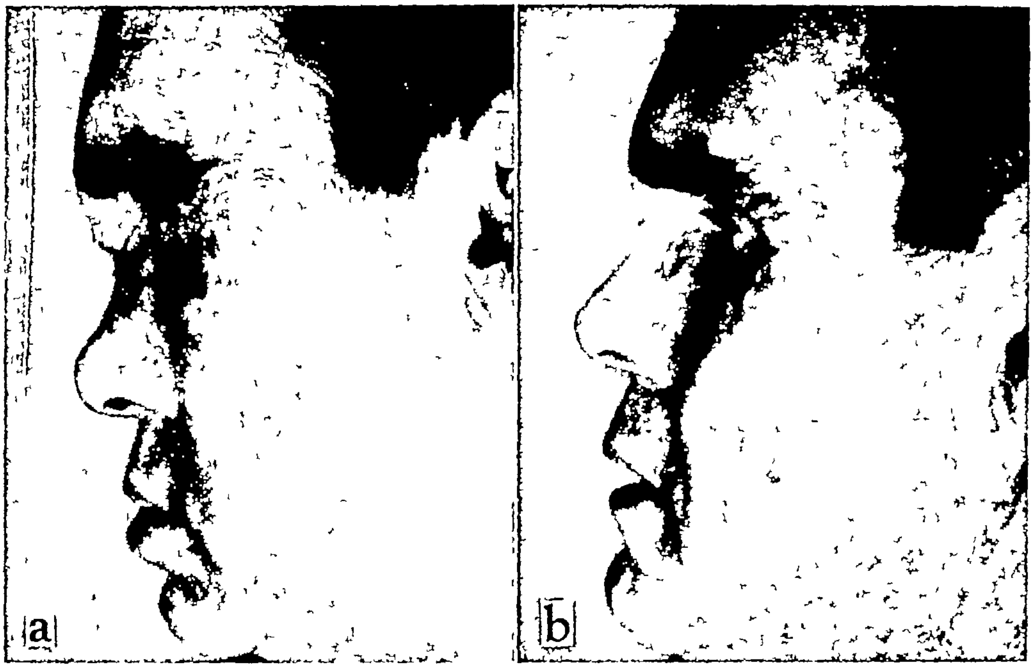
Case 48



c

d

Case 51



Case 51, *a* Patient, aged forty-four, received multiple fractures of both orbits, zygomatic arch, entire maxilla was severed from base of skull, fracture of ridge of nose After reduction of the maxillary fractures (compare with Fig 259, p 432) reconstruction of the ridge of the nose was carried out with an autogenous rib graft

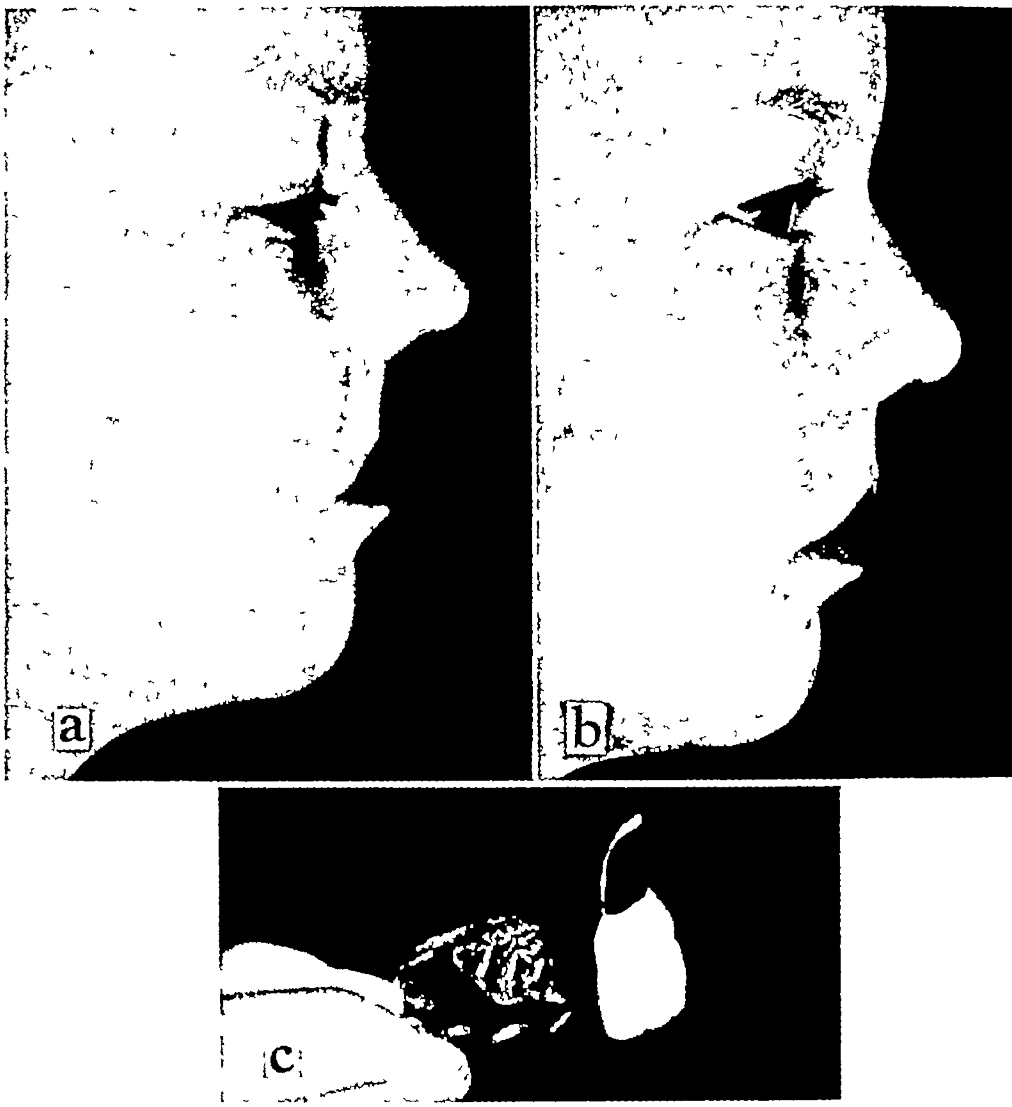
b Two years after the accident

Case 50

Case 50 *a* Saddle nose resulting from an extensive submucous resection of the septum

b Correction by implantation of an autogenous graft of rib cartilage The graft was inserted from a V-shaped incision below the nasal tip

Case 53

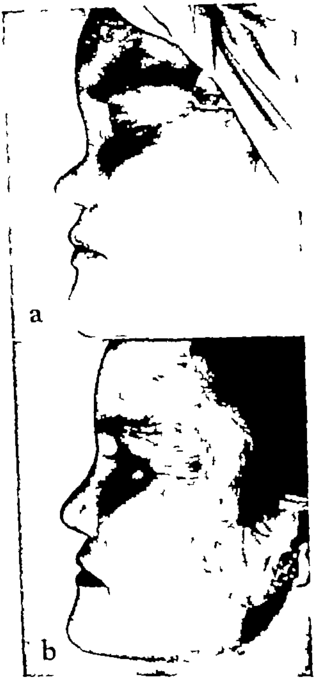


Case 53, *a* Retrusion of upper lip from fracture of upper jaw after automobile accident So-called "dish face" deformity

b After widening the upper labial sulcus with inlay skin graft

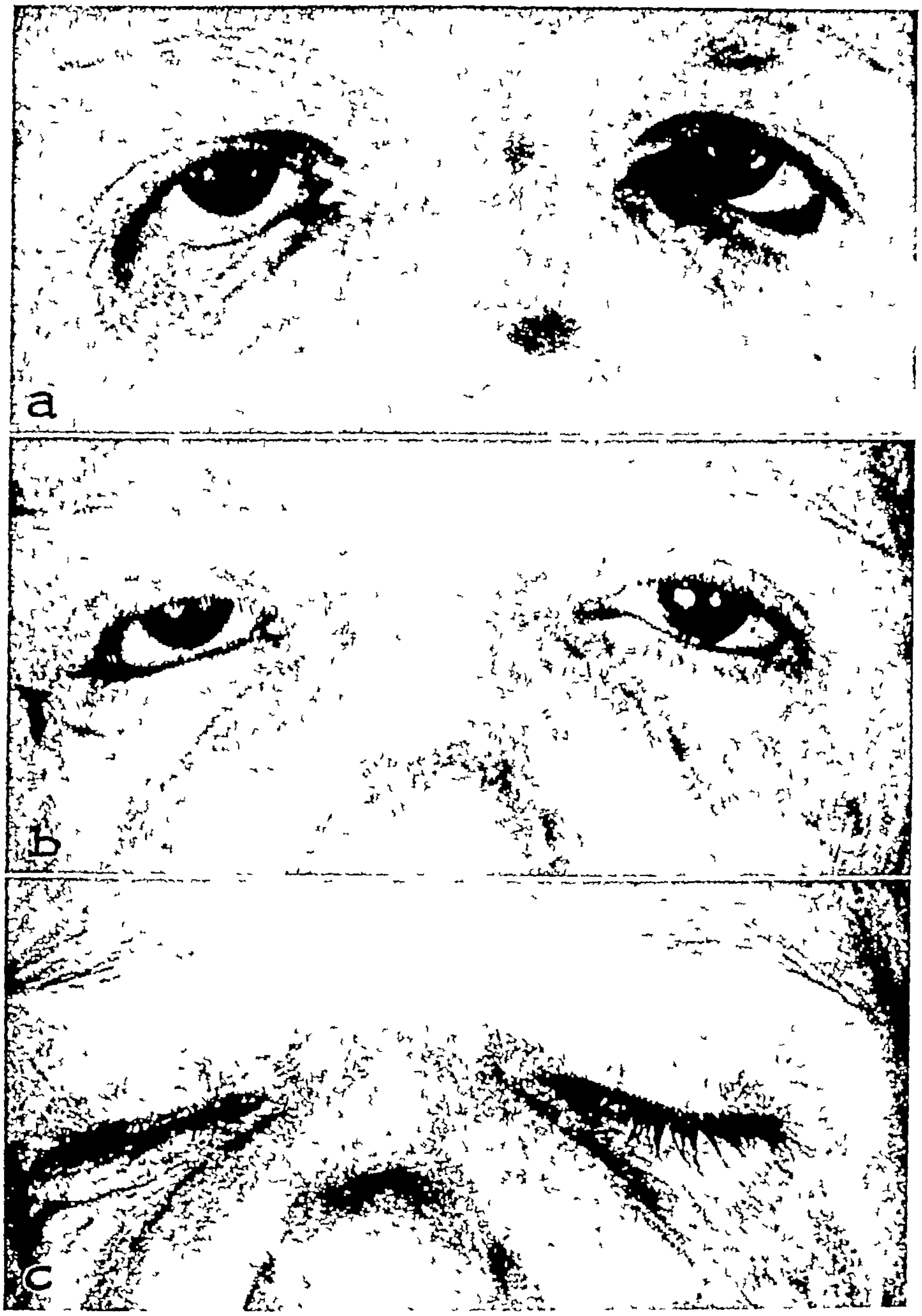
c Patient wears a prosthesis which is fastened to the upper teeth and has an appliance attached to it for forward displacement of upper lip

Case 52



Case 52. *a* Traumatic saddle nose
b After implantation of an autogenous rib cartilage graft.

Case 55



Case 55, *a* Cicatricial ectropion of right and left lower lid after treatment for lupus vulgaris

b, c Repair of the deformity of the right eyelid by the use of two full-thickness grafts one taken from the upper lid of the same eye to cover the upper half, one from the right postauricular region to cover the lower half of the defect (see Fig 203, p 347) Left-lid deformity repaired with a full-thickness graft from the upper lid of the same eye

Case 54

Case 54 *a* Horizontal wound of upper eyelid vertical wound of lower eyelid

b The latter repaired by the halving method to avoid later notching (Fig 216 p 357) The sutures were removed on the fourth day with the exception of the marginal suture which was left in place for ten days.

Case 57

Case 57, *a* Patient, aged 58, with cancer of left lower eyelid V-shaped excision and Dieffenbach flap for closure of defect (compare with Fig 217, p 358) is outlined Since the tumor had only involved the skin it was not necessary to remove the conjunctiva

b Four months after the operation

Case 56

Case 56 *a* Cicatricial ectropion of upper and lower lid after third-degree burn. Note margin of upper lid retracted above level of site of former eyebrow Vision almost completely absent, owing to corneal ulcers and extensive con junctivitis.

b c Repair of both lids in one stage according to the technic of Fig 203 p 317 Use of two full thickness grafts from the hairless region of left upper arm. The intermarginal adhesions were not severed for three months. Vision almost completely restored.

Case 59

Case 59, *a* Patıent, aged fifty-one, wıth extensıve basal cell carcınoma of left lower lıd of one and one-half years duratıon

b Tube flap constructed from mastoıd to clavıcular ıegıon Fıve weeks later tube flap was lengthened Thıs part remaıned untubed Four weeks later the lower pedıcle was clamped as depıcted Four weeks later a mucous membrane graft, taken from the oral sıde of lower lıp, was transplanted beneath flap (see dotted lınes) for replacement of conjunctıva

c Three weeks later the entıre lower lıd was excısed and the flap transplanted Four weeks later flap was seveıed after clamp had been applıed several days prevıously

d, e No evıdence of reactıvatıon four years after the last operatıon

Case 58

Case 58 Basal-cell cancer of lateral half of lower lid. The tumor involves the skin only The width of the excision and the flap to close the defect are outlined To facilitate rotation of the flap a triangle of skin is excised at the extremity of the incision (after Imre) (see Fig 206 p 351) Since parts of the conjunctiva could be left behind, flap did not need to be lined.

Case 60

Case 60, *a*. Defect of lateral canthal angle, including lateral fourth of upper and lower lid after radiation for cancer. A temporal flap was raised, its peripheral end given the shape of the canthal angle. The flap was returned to its original site. After three weeks, it was raised again. Owing to blanching of the peripheral end, transfer was again delayed. After three more weeks, the defect was prepared. Two small turnover flaps were made from the median wound edges to replace the lining. The flap was rotated into the defect. The raw area of the flap bed was closed by undermining the wound edges and skin-sliding. Six weeks later, the pedicle of the flap was severed and adjusted in place, as depicted in Fig. 221, *c*, p. 362.

b, c. Three years after operation.

Case 59

Case 62

Case 61

Case 61 *a* Basal-cell cancer of eyelids with invasion of the orbit treated by removal of eyelids, exenteration of orbit and removal of lateral bony wall of nose. No evidence of recurrence after four years. To close the big hole a lined forehead flap pedicled in left temporal region was transplanted. The flap was mobilized between two parallel incisions, and returned and sutured. The upper incision includes a small part of the hairbearing scalp to replace the eyebrow Two weeks later the right pedicle was severed and sutured one week later the peripheral end of the flap was elevated and lined with a split skin graft. Another week later the entire flap was elevated, and the distal part of the flap bed covered with split skin graft Blanching of the distal parts of the flap made another delay of transfer advisable

b Two weeks later the flap was transplanted into the defect. The defect edges were denuded and split into two layers. The lining of the flap was sutured to the deep layer the skin to the skin edges.

c Six weeks later the flap was severed from its pedicle and the flap was adjusted in place. The patient wore spectacles with ground glass on the left side to conceal the deformity

Case 63 Sagging pouches of lower lids, corrected by excision along the base The lower incision runs along a natural fold A triangular piece of skin was removed from the lateral end of the incision to avoid puckering (compare with Fig 233, p 389)

Case 62

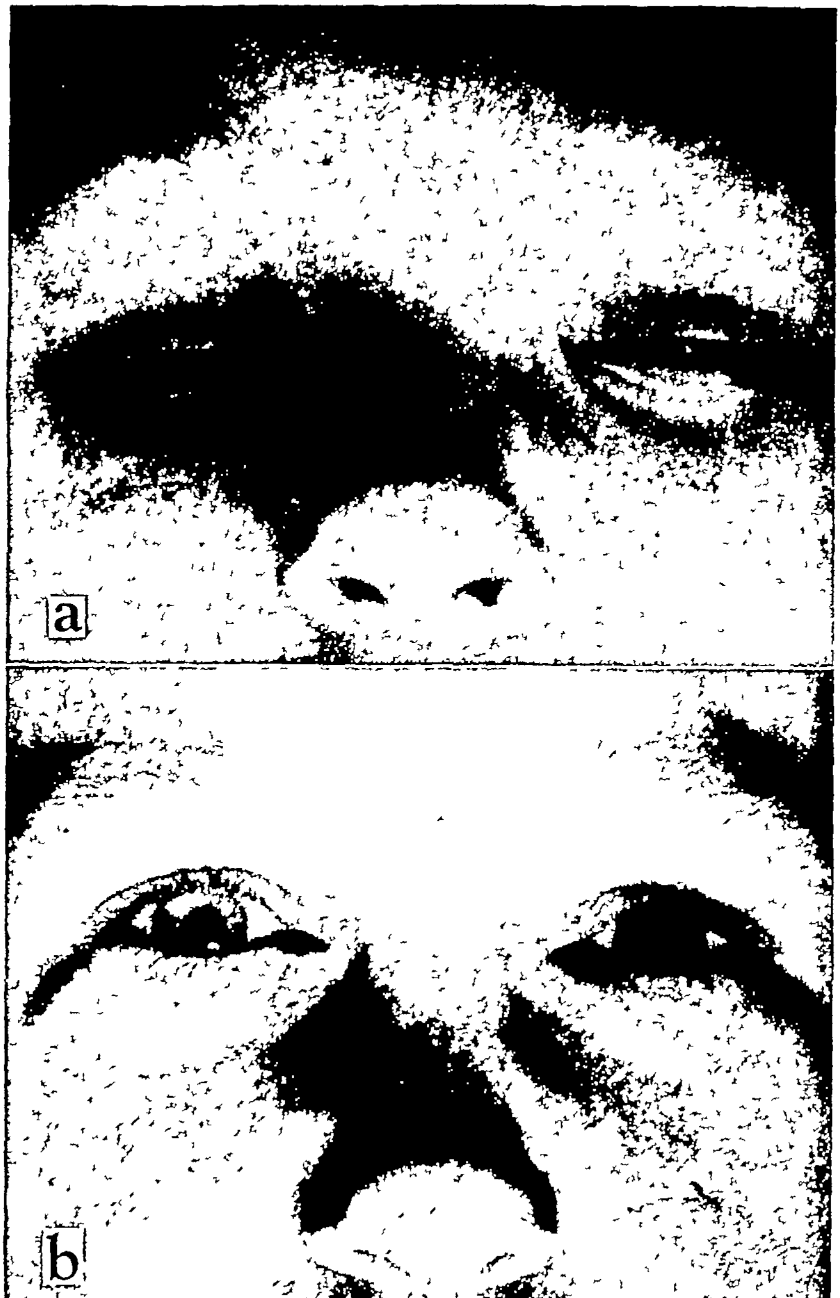
c

Case 62 *a* Extensive basal cell carcinoma of right orbital region of ten years duration Mixed tumor of left parotid gland.

b Radical operation consisting of removal of the right eye right half of nose wide excision of the tumor Periosteum of the orbit could be preserved.

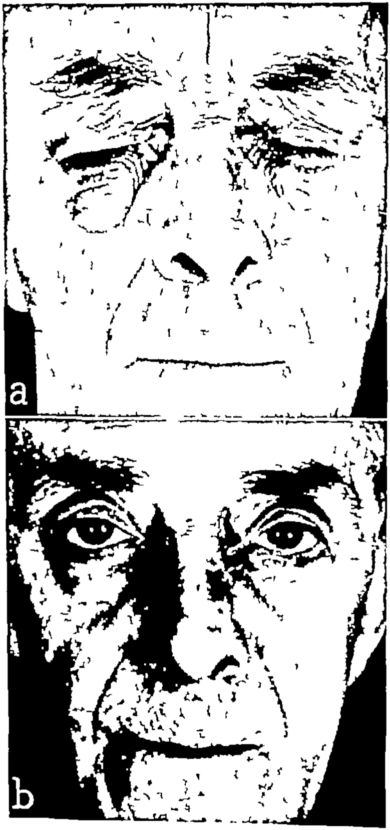
c Two months later an inlay skin was transplanted to line the orbital cavity Two years after the operation small recurrence at the nose which was electrocoagulated No further reactivation four years after the first operation Patient died from other causes.

Case 64



Case 64, *a* Girl, aged nine, with bilateral epicanthus (Mongolian fold). *b* After bilateral epicanthus operation with double Z-plasty

Case 63



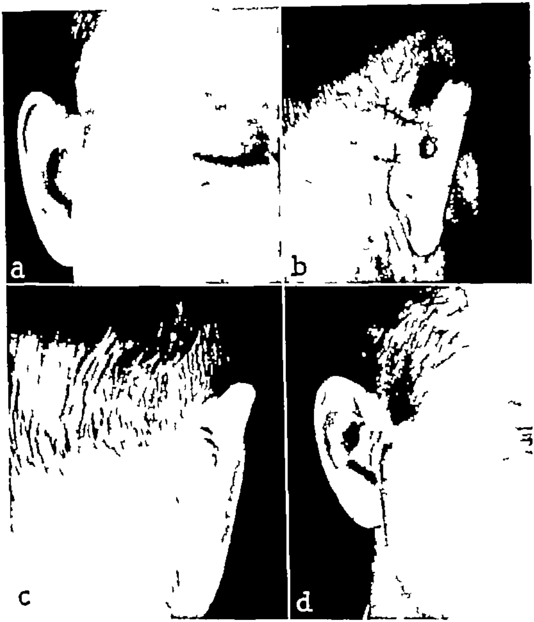
Case 66

Case 66, *a*· Patient, aged sixty-two, after excision of helix and anthelix for removal of squamous cell carcinoma

b Transplantation of mastoid flap in same stage of operation Donor area of flap at mastoid region skin grafted

c Three weeks later partial separation of flap Four days later separation of flap and adjustment of the same

Case 65

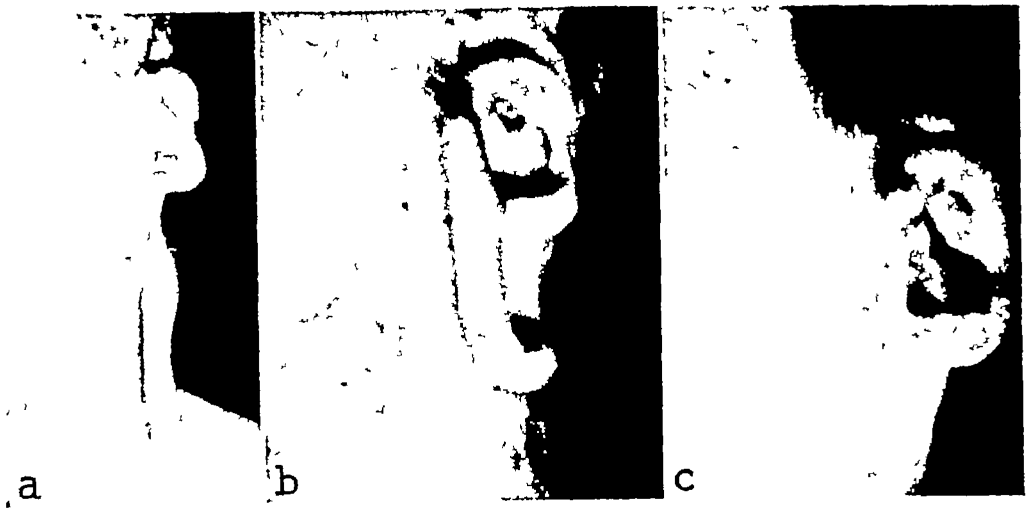


Case 65 *a* Bullet wound through concha

b A double pedicle flap in postauricular region one third larger than required, was elevated and returned. A rim of skin surrounding the edge of the defect to be hinged forward later on was elevated and returned. After two weeks, the pedicle near the hole was severed and sutured

c d After another two weeks, the whole flap was raised the rim of skin surrounding the edge of the hole in the concha was hinged forward the auricle was held back and the flap sutured into the defect After three weeks, the backward tilt of the ear was overcome by severing the central pedicle in the mastoid region undermining and advancing the flap Resulting raw surface was skin grafted.

Case 68



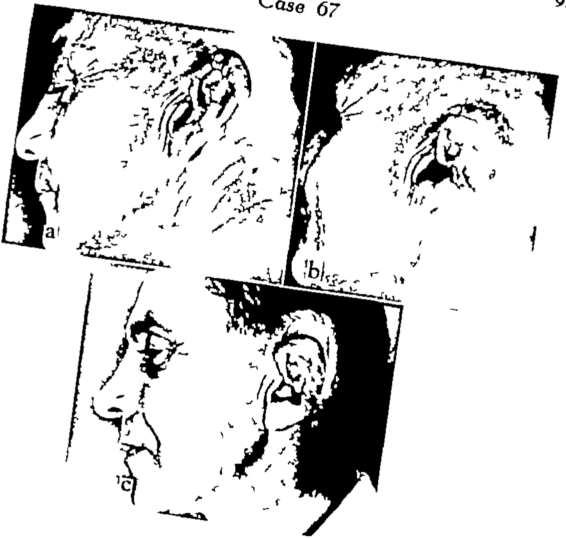
a b c

Case 68, *a* Burn of face and ear Helix absent The concha was adherent to the mastoid region The concha was moved forward by excision of the cicatricial tissue of the postauricular region, and the raw surface was skin-grafted A cervical tube flap was made to reconstruct the absent helix

b Four weeks later, the inferior pedicle of the flap was transferred to a place just above the tragus

c. Three weeks later, the pedicle in the mastoid region was severed One week later, the flap was opened along its seam, and draped around the auricle in such a way as to form the helix

Case 67



Case 67 *a* Patient with squamous cell carcinoma of ear Grade I (Line of excision marked with dotted lines.)

b Subtotal removal of ear and mobilization of mastoid flap between two parallel (upper and lower) incisions. Two weeks later severance of posterior pedicle depilation of flap and transplantation of skin graft to depilated area. Three weeks later elevation of entire flap and transplantation of rib cartilage beneath the flap

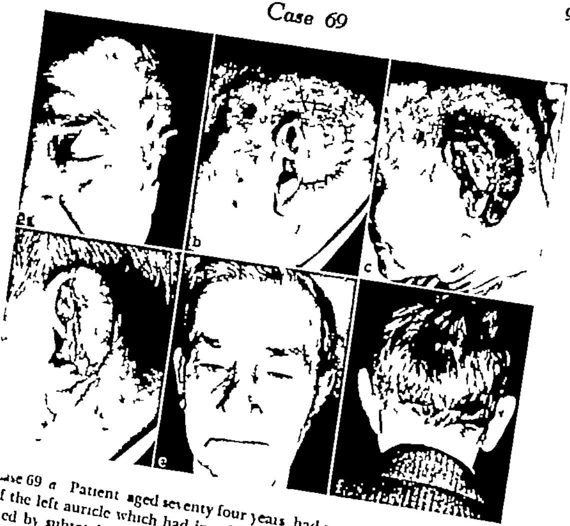
c Six months later elevation of composite mastoid flap flap attached to ear lobe, skin grafting of post auricular raw surface.

Case 70

Case 70, *a:* Boy, aged eight, with subtotal congenital absence of left ear Elevation of mastoid flap, transplantation of rib cartilage. Five weeks later depilation of mastoid flap and transplantation of skin graft to depilated area

b, c· Four months later mastoid flap was elevated The remnants of the ear were used to form ear lobe and tragus The posterior raw surface was skin grafted (Note in *c* that left ear was made larger to compensate for possible retardation of growth)

Case 69



Case 69 *a* Patient aged seventy four years had squamous-cell cancer at the rim of the left auricle which had invaded the cartilaginous framework. It was removed by subtotal resection of the auricle Reconstruction was begun one year later

b The flap to be raised from the mastoid region was outlined according to pattern and made one third larger than required. Owing to the fact that the base of the flap came to lie along the base of the defect—that is came to lie along a scar—the flap had to be raised in stages. It required four stages, two weeks apart During the first stage the posterior half of the flap was depilated (see p 198) In the last stage a rib-cartilage graft suitably carved to conform with the new field and diced cartilage to fill the space between the latter and the base of the flap were inserted beneath the flap.

c Ten weeks after the last stage the flap and cartilage graft were raised and the flap sutured to the defect edges. A mold of dental compound was made to hold the flap in protrusion corresponding to that of the other ear The mold was covered with a split skin graft, inserted behind the ear and held in place with sutures (compare with Fig 236 *c* p 100) The mold was removed after ten days

d-f Patient two months later

Case 71

Case 71, *a*, *b* Protruding ears due to absence of the anthelix
c, *d* Reconstruction according to the method of Fig 238, p 404

Case 70

Case 73

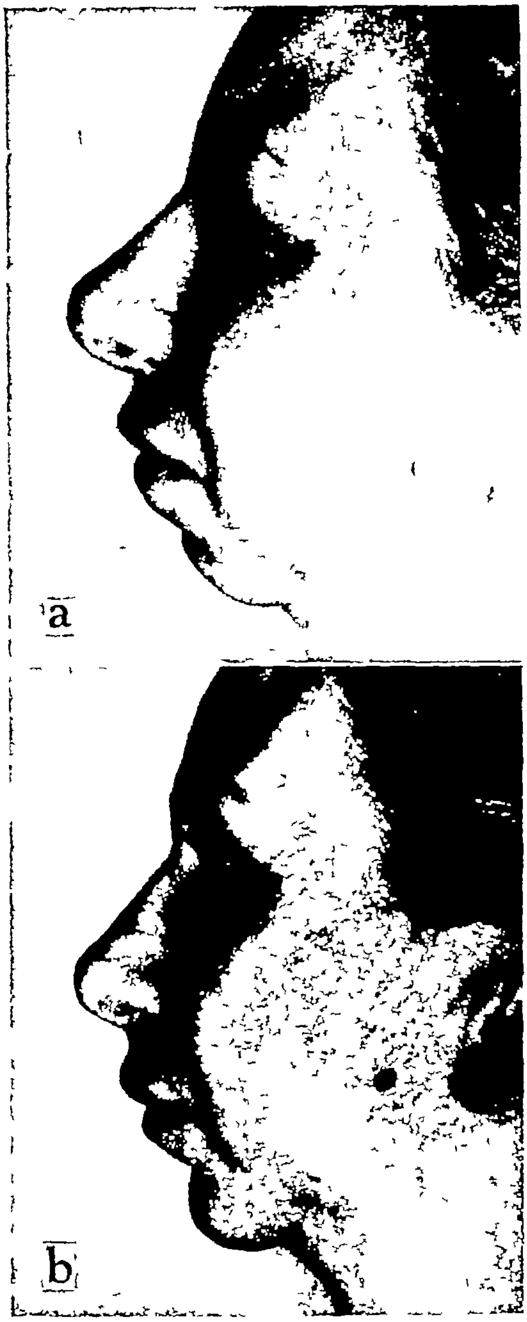
Case 73, *a*. Patient, aged nineteen with mandibular prognatism and malocclusion of the teeth

b· After correction of mandibular prognatism through osteotomy of the ascending ramus Teeth are in satisfactory occlusion

Case 72

Case 72 *a* Bilateral protrusion of ears from absence of anthelix.
b After bilateral ear plasty consisting of construction of anthelix and excision of redundant skin.

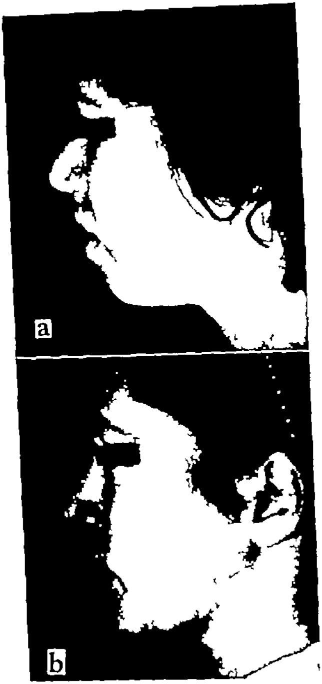
Case 75



Case 75, *a* Patient, aged thirty-nine, with marked retrusion of mandible Teeth, however, were in perfect occlusion

b After correction of the retrusion of mandible through build-up of the chin with two superimposed autogenous rib cartilage grafts which were inserted from incision below the chin and held in position with two wire mattress sutures Note that nose appears smaller after build-up of the chin

Case 74



Case 74 *a* Patient, aged twenty four with retrusion of chin Teeth were in good occlusion.

b After correction of retrusion of the chin with bone grafts from ilium which were inserted through an intraoral incision (see p. 446).

Case 77

Case 77, *a, b* Patient, aged thirty-four, with contracture of neck from extensive third degree burn.

c, d After excision of contracting scar and platysma and application of split skin grafts Patient wore a brace (see Fig 270, p 458) for three months day and night and for an additional three months overnight only.

Case 76

Case 76 *a* Patient, aged twenty five with "bird face" from extensive retrusion and maldevelopment of mandible, open bit, teeth of lower jaw one inch behind teeth of upper jaw (compare with Fig 269*a* p 448)

b Repair of micrognathia with bone graft from ilium which was fastened upon the anterior part of the mandible from an incision below the chin (compare with Fig 268 p 448) (lengthening of mandibular bone was impossible owing to aplasia of the bone). Eight months later the lower gingival sulcus was enlarged and deepened with an inlay skin graft. A dental prosthesis was inserted into this pocket with artificial teeth. Good occlusion of these teeth with teeth of upper jaw (compare with Fig 269*b* p. 448) Note that nose, which has not been operated upon appears smaller after build up of chin

Case 79

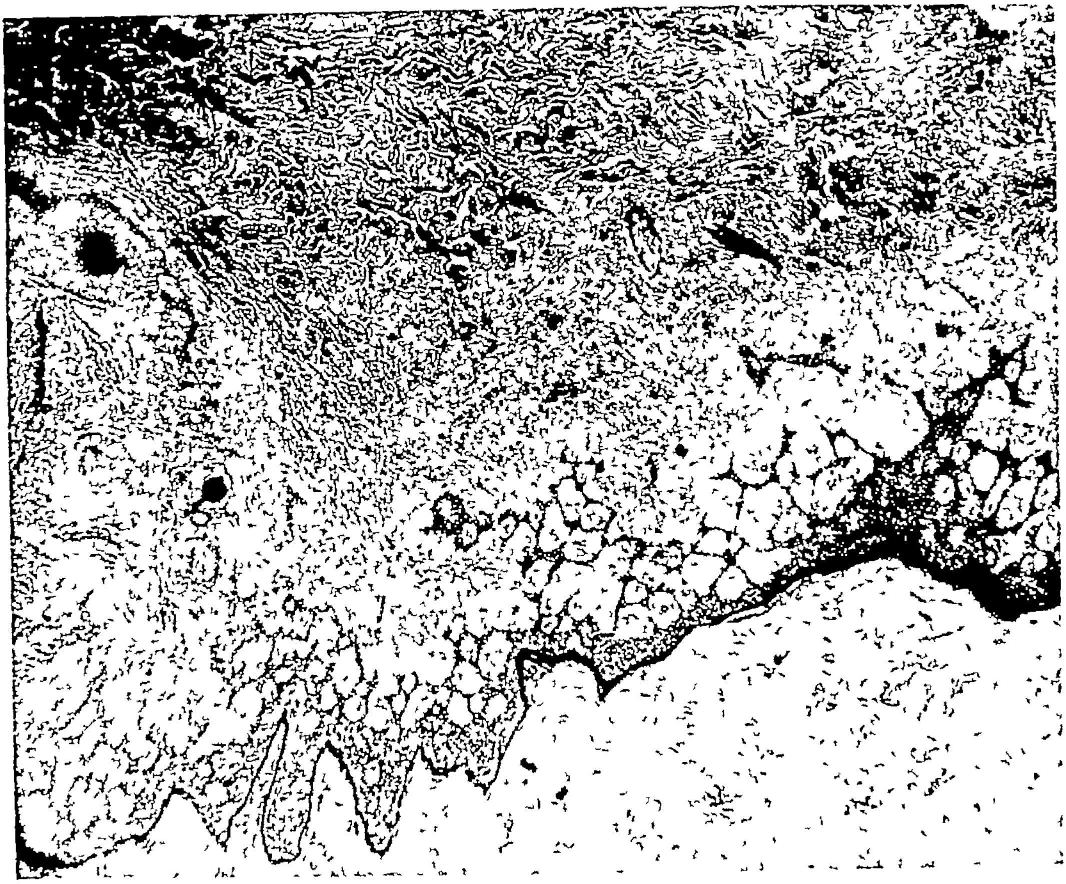
Case 79, *a* Patient, aged thirty-eight, with hypertrophic and pendulous breasts

b One year after breast plasty with transplantation of nipples as free grafts.

Case 78

Case 78 *a* Patient aged twenty five, with pendulous, hypertrophic breasts. *b* Six months after breast plasty with preservation of function of the glands.

Case 81

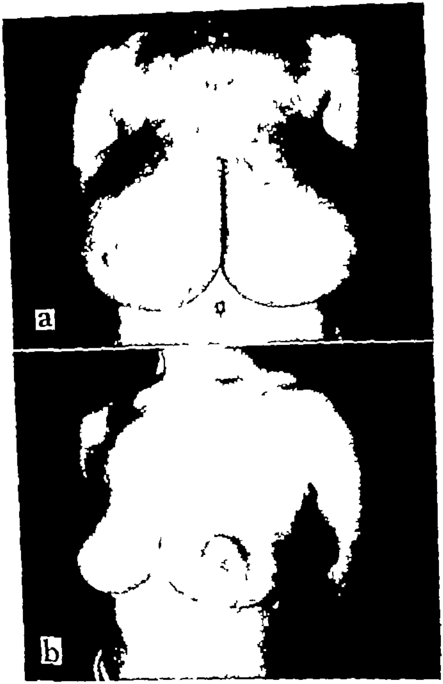


Case 81, *a* Patient, aged thirty-two, concerned about her small breasts, wanted them enlarged

b Eight months after increase of size of breasts with free derma-fat grafts from the gluteal folds, grafts are palpable as hard masses of fist size

About three weeks after the operation the left breast drained from a small sinus This gave an opportunity to remove the sinus and a small piece of the graft for microscopic examination All epidermis had presumably been removed from the derma-fat graft before it was placed between the breast and chest wall with the dermal side toward the chest, yet the microscopic picture (see above) shows a well preserved layer of epidermis as well as the dermal layers, the fat layer is replaced by dense fibrous tissue The drainage was caused by an epidermal inclusion cyst.

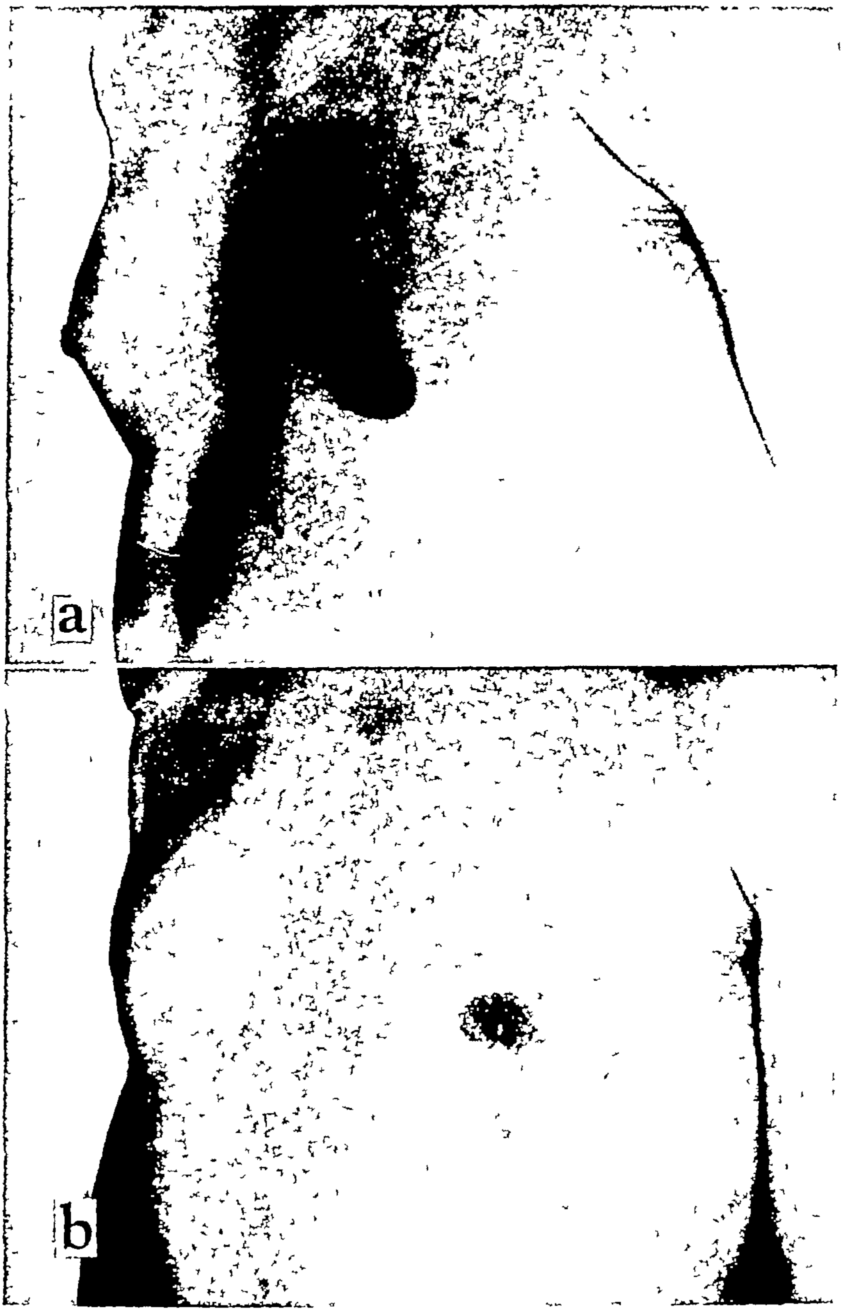
Case 80



Case 80 *a* Patient aged twenty-seven with marked hypertrophy of both breasts

b Seven months after breast plasty with transplantation of the nipples as free grafts. Patient went through two pregnancies engorgement of breasts could promptly be overcome by injection of stilbestrol

Case 82



Case 82, *a* Patient, aged thirty-two, with gynecomastia
b Excision and repair of gynecomastia after the method of J Webster (see p 488)

Case 81

Case 84

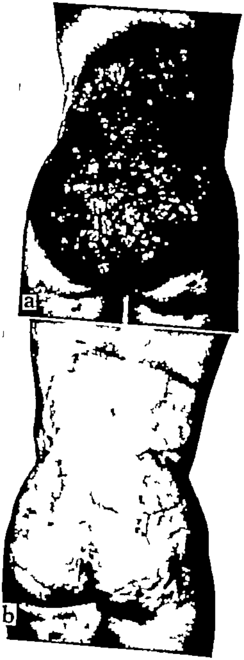
Case 84, *a* Patient aged sixty-seven, with extensive x-ray burns of sacral region after irradiation of a carcinoma of the bladder

b After excision of the x-ray damaged skin four local flaps were outlined

c After excision of necrotic sacrum and coccyx and elevation of flaps

d One year after flaps had been rotated into the defect

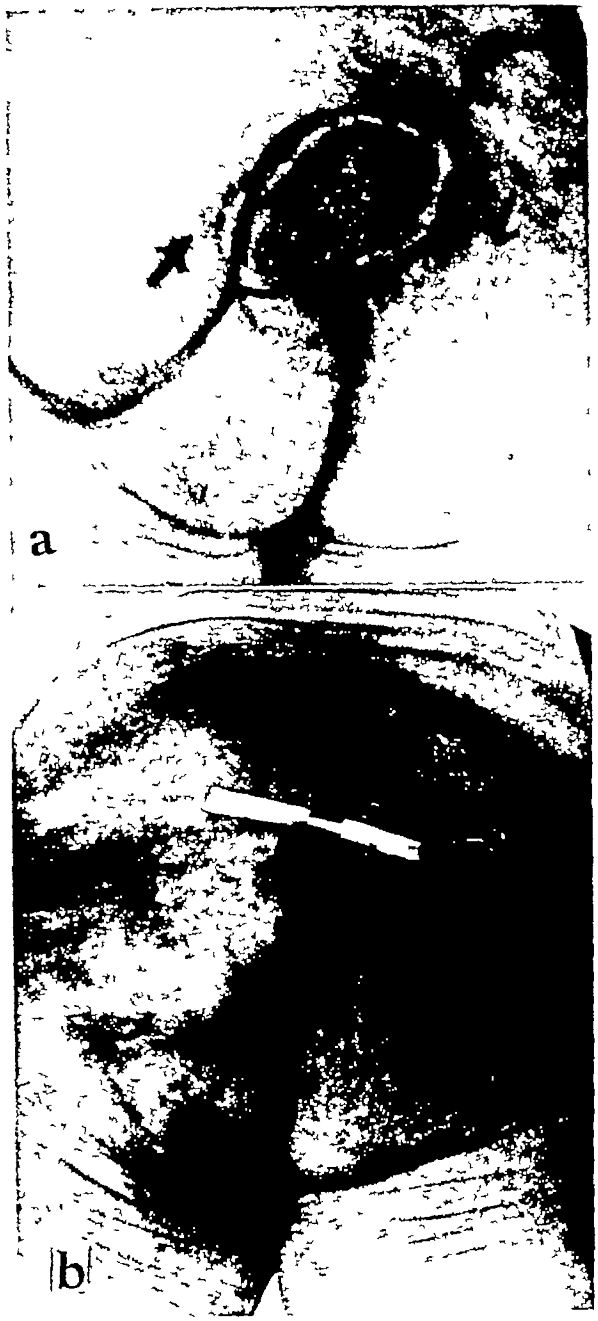
Case 83



Case 83 *a* Boy aged seventeen with large hairy birthmark (pigmented dermal nevus) In some places the nevus was 5 cm. (2 inches) thick It had crevices particularly around the anus with frequent infections.

b The birthmark was excised in seven stages and skin grafted with thick split skin grafts in each stage.

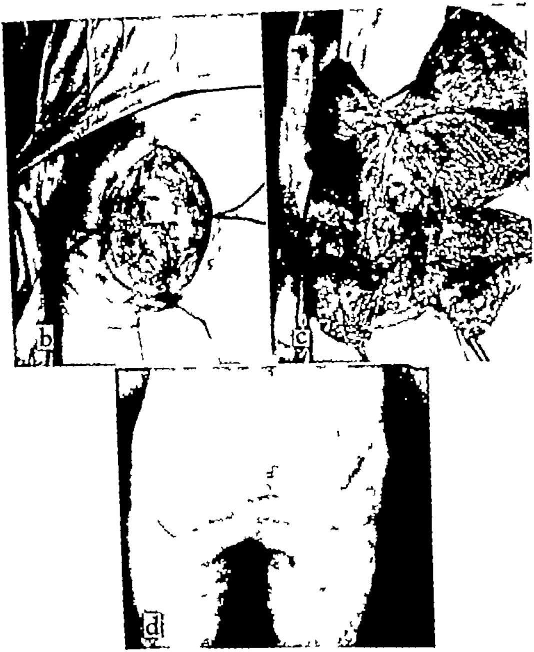
Case 85



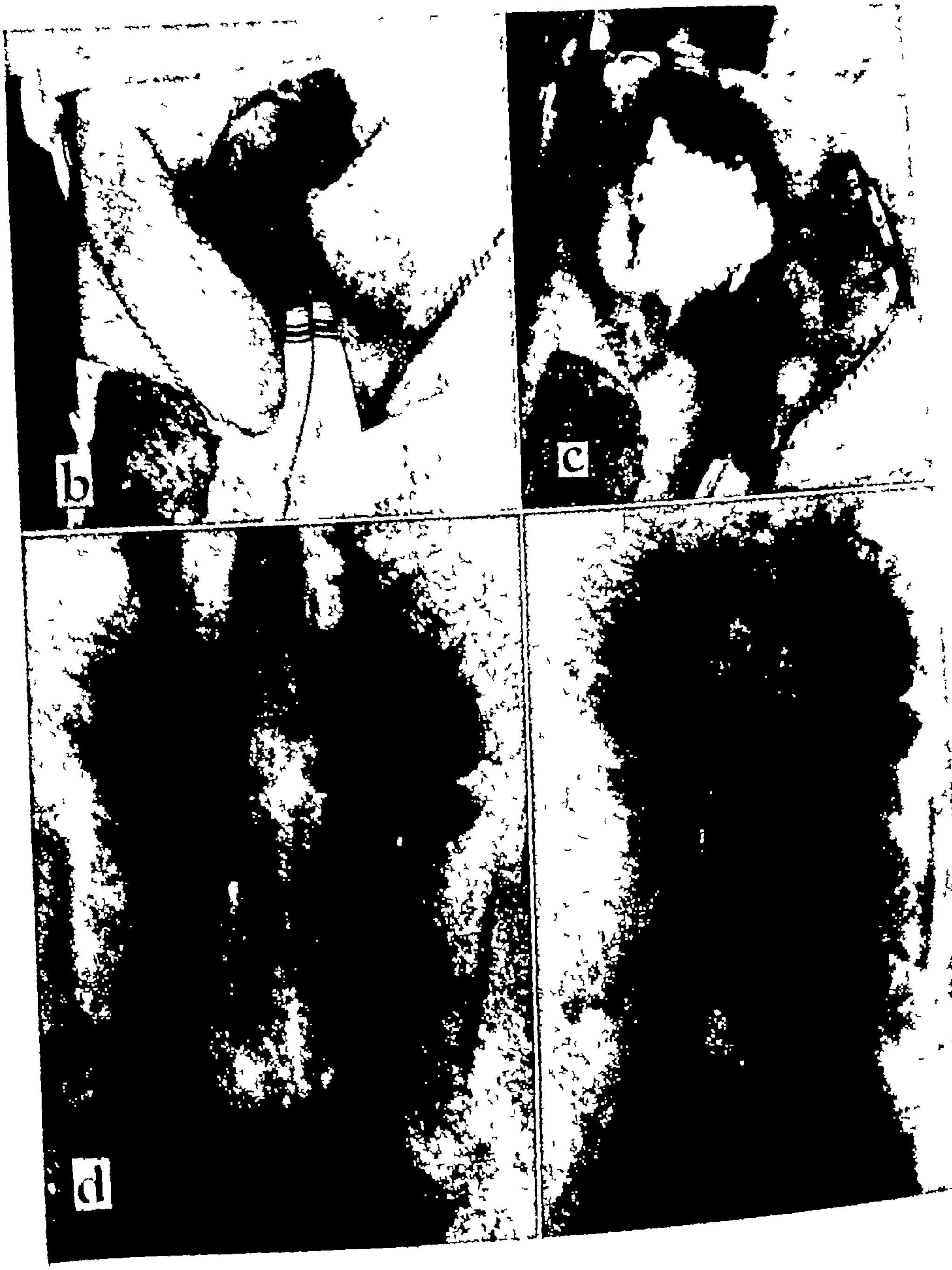
Case 85, *a* Patient, aged seventy-two, with decubital ulcer Local flaps for rotation are outlined

b Four weeks after operation

Case 84



Case 86 (Continued)



Case 86

a

Case 86 A twenty-year-old patient was working on a printing machine. His trousers were caught between steel rollers just above the knees. They were pulled off along with the rest of his clothes including the leather belt, which tore apart over his back. The accident resulted in complete denudation of the testicles and penis, and contusion of his back. The patient was in extreme shock for which he was treated immediately. About two hours after his admission the emergency dressings were changed it was found that the scrotum as well as the entire skin of the penis, was torn off. The skin of the penis was hanging on a narrow thin pedicle at the corona of the glans this was replaced and a pressure dressing applied. The scrotum however was not replaced immediately since the patient's condition did not permit more repair work, but was placed in saline solution which contained 400 000 units of penicillin. It was replaced the next day and held in place with a light pressure dressing. The dressings were changed on the fifth day. The scrotum was found black and had to be removed. The distal two-thirds of the skin of the penis had taken completely the proximal third, however was necrotic. After three weeks the patient was referred for reconstruction of the scrotum. A double pedicled oblique bridge flap was formed on the anteromedian surface of the thigh. The upper incision was made just below (about 2.5 cm [one inch] distally) and parallel to the crease of the groin

(Continued on next page)

Case 87, *a*: Patient, aged forty-four, was circumcised. The operation resulted in loss of entire skin of penis. The corona glandis became adherent to the scrotum, and the shaft of the penis was buried in the scrotum.

b: The corona was freed from the scrotum, the shaft of the penis was dissected free, and covered with a skin graft.

c: Two months after operation. Patient stated to have no discomfort in any way. A similar follow-up report was received five years later.

Case 86 (Continued)

The measurements of the flaps were 15 by 8 cm Both flaps were elevated from the fascia lata The testicle and spermatic cord were now buried beneath the flap. The proximal and posterior part of the plexus was resting upon the narrow strip of skin of the crease of the groin The remainder of the posterior part of the plexus and the testicle would have come to lie upon the raw surface of the thigh To prevent the testicle from growing to the donor area and also to prevent the flap from becoming reattached to its donor area the donor area was skin grafted at this stage, using a nylon backed thick-split graft, cut with the dermatome from the median surface of the same thigh The flap was now sutured to the wound edges of the donor area in the region of the spermatic cord it was sutured to the raw area *b* A heavily padded pressure dressing was applied Within the following weeks the pedicles of the flaps were gradually severed. The median pedicles were partially severed nine days after the first operation five days later the lateral pedicle was severed one-third from each side, and a laboratory clamp was applied to the median third (*c*) which within the following few days was gradually crushed During the same stage the raw area of the proximal third of the shaft of the penis was skin grafted (*c*). One week after the third operation the flaps with the testicles closely attached were elevated The skin grafts beneath them had taken well the nylon backing was removed The flaps however became cyanotic, hence were returned to their former site. One week later the flaps were again raised and were anastomosed to each other in the following manner The lateral pedicles became the posterior and the median pedicles the anterior raphe the lower oval openings of the flaps were sutured together thus forming the bottom of the new scrotum The posterior rim of the upper oval opening was sutured posteriorly to the perineal region the anterior rim sutured to the pubic region (d)

Upon the request of a follow up report, eight years after the accident the patient wrote as follows "I am happy to report to you I am feeling fine. My testicles do not bother me at all I have not worn my suspensory to hold my testicles up for the last two years. I am also happy to tell you I have a fine young son He is two and one half years old now I have a job working as an airplane mechanic I have also been playing baseball for the past three years. So you can see I am feeling fine. In fact I don't think I have ever felt better"

Case 88

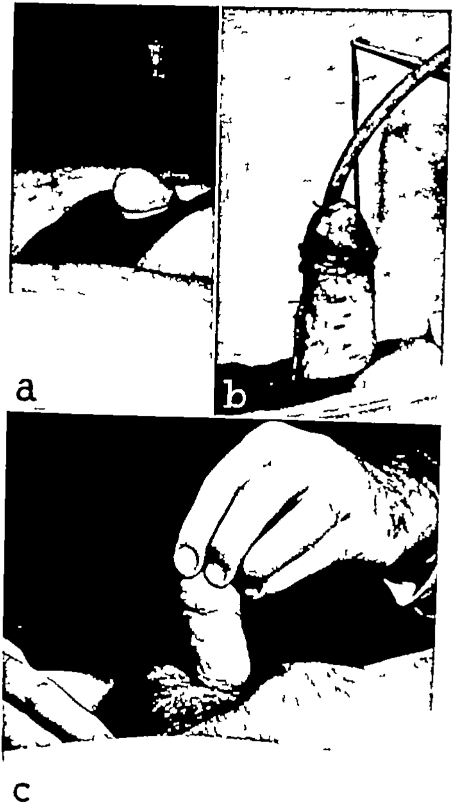
Case 88, *a* Patient, aged eighteen, born with almost complete absence of the vagina Since age seventeen she noticed a monthly pain in lower abdomen which repeated itself almost clocklike on the twenty-eighth day From this time on the breasts started to develop A gynecological examination under anesthesia revealed no uterus but both ovaries

b Reconstruction of vagina with inlay skin graft Skin grafts were wrapped around a stent of plexiglass Grafts were taken from the hairless region of the median surface of the thighs

c Rubber tubing fastened to a belt held the stent in place

d After stent was worn for three months day and night and after another three months only at night, vagina remained wide open Patient has married, although some subsequent shrinkage occurred, intercourse is satisfactory They adopted a child

Case 87



Case 89, *a* Patient, aged twenty, was a pseudohermaphrodite who had been brought up as a female At the age of twelve an exploratory laparotomy was performed elsewhere which did not establish the sex The pelvis was found empty and gonads could not be found anywhere else Endocrine studies failed also to clarify the sex pattern Examination at the time of admission revealed an individual, five feet seven inches tall, 163 pounds, large features, hands and feet, breasts small, her voice only slightly low, hair distribution was female, no facial hirsutism, and hips were a little broad The inguinal regions were well padded with subcutaneous fat tissue and for this reason were difficult to palpate There was no evidence of a hernia or a mass The clitoris was about 5 cm long and resembled a penis, it was held downward by a chordee and had complete hypospadia The urethra opened into a vestibule surrounded by small labia minora Behind it was a small fistulous-like opening representing the vaginal outlet A probe could be passed through this opening for about 6 or 7 cm Labia majora present and of normal size—they were empty These findings suggested that the individual was a pseudohermaphrodite and probably of male pattern The psychosexual patterns were however female At the age of nineteen she fell in love with a boy of her age She requested reconstruction of the vagina and amputation of the phallus *b* The vagina was reconstructed with a free inlay skin graft Amputation of the phallus was deferred Subsequently she developed symptoms of a strangulated left-sided inguinal hernia. Operation revealed however a normal sized testicle with appendages and spermatic plexus surrounded by a hydrocele A testicle was found in the right inguinal region It was left behind Subsequently the patient decided to remain female and castration and further estrogenization was carried out Patient married a male and intercourse is satisfactory to both Amputation of the phallus is indefinitely postponed since erection of the same upon sexual excitation provides a feeling of "pleasure" to her

Conclusion This individual proved to be a male pseudohermaphrodite It must be assumed, although actual proof is lacking, that the testicle secreted a sufficient amount of female hormones to cause a gynecoid orientation The psychosexual trauma inflicted later in life as the result of the discovery of the testicles would have increased had the patient been fitted to the gonadal sex But through reconstruction of the vagina, castration, and estrogenization, the gynecoid pattern could be enhanced

This case proves that the gonads although primarily influencing the secondary sex characteristics of an individual and making the individual anatomically male or female may not direct sex orientation and psychosexual behavior

Case 88

Case 90

Case 90, *a* Extensive incisional hernia of lower half of abdomen

b The operation consisted of the Mayo overlap method of closure. The flaps were made longitudinally of fascia and the rectus sheath There was much tension on the whole area hence a dermal graft was utilized which consisted of the excised redundant skin minus its epidermis The patient wore an abdominal belt for six months There is no evidence of recurrence thirteen months after operation Patient works as a janitor of a school

Case 89

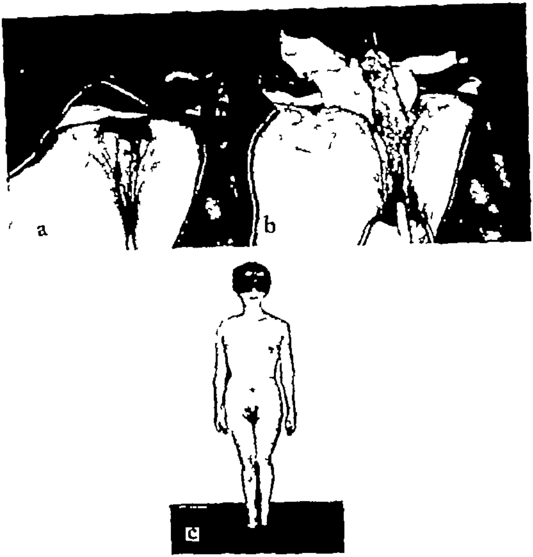
Case 91 (Continued)

along the posterior wall of the abdomen toward the left kidney The surgeon was unable to palpate any growths in the region of either kidney. A partial amputation of the clitoris, which was one and one-half inches long, was performed for symptomatic relief An exploration of the adrenal glands was abandoned It was hoped that as she grew older a possible tumor of the glands (adrenal) could be more easily dealt with She was readmitted two years later for exploration of the adrenal glands, the right one was found normal, the left one could not be explored since operation had to be discontinued on account of acceleration of the pulse After she was four years old hair started to grow on the face and extremities At six years of age she had a bloody discharge from the vagina for about two days This occurred again for four days at age of fourteen years Her voice grew deeper at age sixteen Although early in youth she liked to play with girls, she became later on attracted by boys as well as by girls The clitoris after the partial amputation started to grow soon again Ever since she can remember she experienced occasional erection of the clitoris, even at night, erection became more and more painful because the stump of the clitoris had been buried beneath the pubic skin at the first operation Erections occurred upon excitation by men as well as women In Fig *a* (lithotomy position) the clitoris is seen bulging beneath the pubic skin

She was referred for reconstruction of the vagina, which apparently was absent, and removal of the clitoris The urinary hormone assay were reported as follows June 22nd, 1947, 17 Ketosteroids 53 6 mg per 24 hours September 22nd, 1953, 26 1 mg and 32 3 mg Urine volume 450-550 cc per day

Operation was carried out under general anesthesia with the patient in lithotomy position (Fig *b*) Between the underdeveloped labiae a wide urethral opening was disclosed, more posteriorly than normally situated A catheter was passed into the urethral opening but failed to withdraw urine Only after several more attempts could the Foley catheter be passed into the bladder Thus it became obvious that the wide urethral opening was the uro genital sinus into which vagina and urethra opened An incision was made from the posterior rim of this opening through the perineum toward the rec tum The incision was deepened for about an inch When the vaginal cavity was reached, the vagina was of normal width but little shorter than normal There was no cervix palpable or visible and no anterior enlargement simulating a prostate A mobilization of the vagina was carried out to join it to the skin wound at the perineum An incision was now made over the buried clitoris and a penis-like structure with two corpora cavernosa was dissected free It measured 4 x 1 inch A typical operation for amputation of the penis was carried out, leaving only a little stump where the corpora divided into a right and left branch The mucous membrane was sutured over it Recovery was uneventful

Case 91

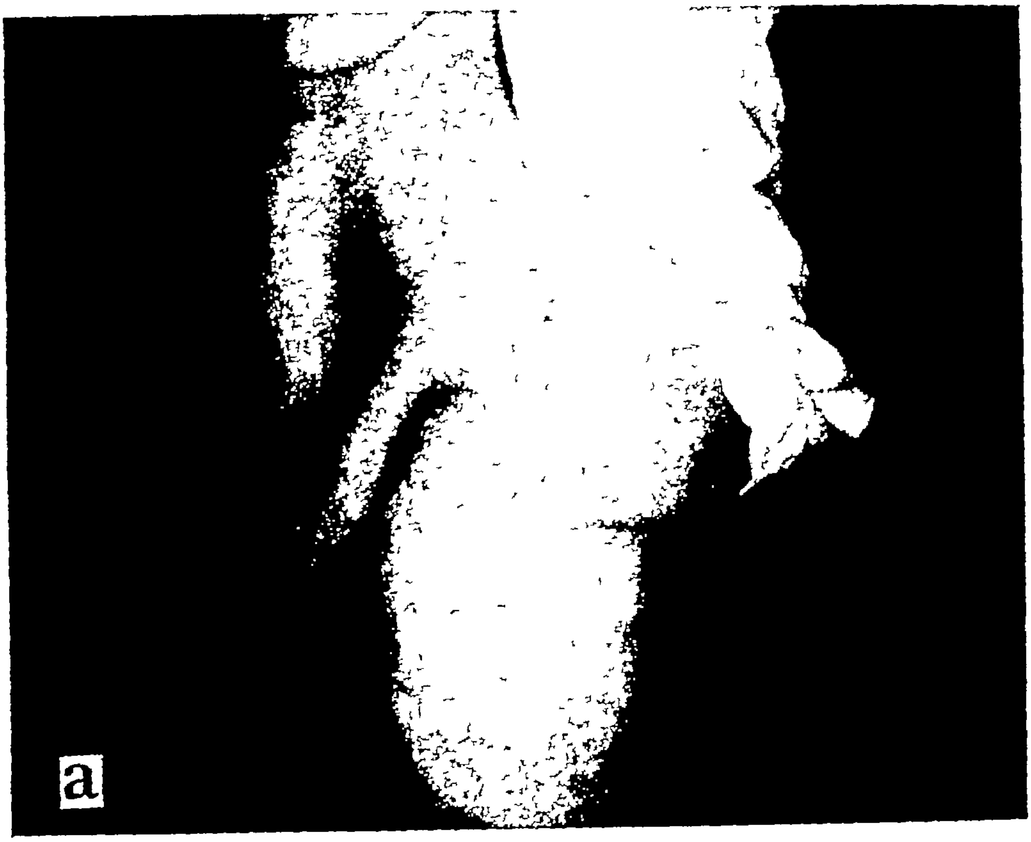


Case 91 *a* This patient had been formerly classified by the author as female pseudohermaphroditism (Plast. & Reconstruc Surg 16 201 1955) but from subsequent studies it becomes evident that the diagnosis must be corrected. The problem of female pseudohermaphroditism is complicated by the fact that the vast majority of female hermaphrodites actually have congenital adrenal hyperplasia, and this individual appears to be one of these cases.

Patient, aged nineteen who at birth was pronounced female She has one brother Family history is irrelevant. When one and one half years old mother noticed an enlargement of the child's clitoris After consultation with several physicians an exploratory laparotomy was carried out At operation there were found a normal infantile uterus tubes and ovaries. The urachus was persistent and quite definite and by palpation seemed to disappear as it passed laterally

(Continued on next page)

Case 92



Case 92, *a*: Patient, aged sixty-one, had six children and with each preg-nancy the adipose tissue of the abdomen enlarged and became flabby like an apron

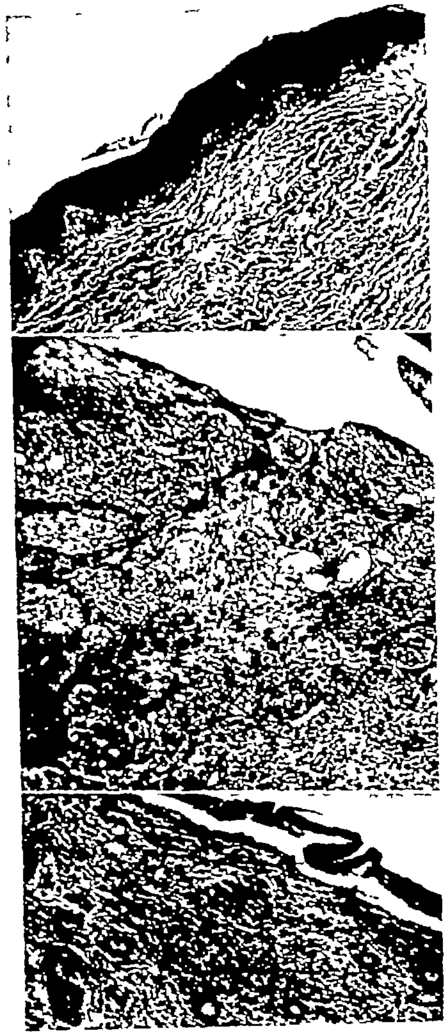
b, c, d: Three months after excision of the redundant skin and fat tissue and repair of a wide diastasis of the rectus muscle and transverse shortening of the fascia and muscle with a Mayo overlap technic No symptoms or recurrence after 15 months

Case 91 (Continued)

She returned to her endocrinologist and estinyl was administered. This apparently caused intrauterine bleeding resulting in hematometra since the cervix was absent. She consulted the gynecologist who upon operation found a blind vaginal pouch unconnected with the uterus upon abdominal section the uterus was found markedly enlarged tubes and ovaries appeared normal the abdomen was closed and the operation continued by vaginal approach the operative procedure consisted of connecting the vaginal vault to the presumed cervix allowing drainage of the massive hematometra. Biopsies which had been taken from the ovaries showed immature structures with follicles in abundance. She then was placed on cortisone treatment. The hair of face and of extremities decreased almost immediately the breasts started to develop She has irregular vaginal bleedings or rather spottings, sometimes lasting about five days

Her endocrinologist, Dr A. M Bongiovanni summarizes her and similar cases as follows "The basic defect is an inability to synthesize cortisone As a result of this the pituitary puts out very large amounts of ACTH in an attempt to force the synthesis of cortisone but due to a congenital lack of the enzymes in the adrenal cortex necessary for the synthesis the adrenal is unable to respond properly However instead of making cortisone the gland does manufacture very large amounts of androgen since there is no defect in its ability to do so Since the androgens do not satisfy the pituitary the ACTH stimulation continues unabated This whole disease begins in the uterus and the female fetus whose organs are entirely normal otherwise is under the influence of androgens which bring about changes only in the external genitalia but always leave the internal genitalia undisturbed Therefore the ovaries and uterus are practically always normal The surgical approach requires only correction of the external genitalia However for proper feminization to occur at the right age cortisone must be administered continuously throughout life The doses of cortisone employed are very small and approximate the amount that the normal adrenal would be making These doses in no way resemble those used in rheumatoid arthritis or other such diseases. When the small dose of cortisone satisfies the pituitary the adrenals no longer make androgens and the entire picture is reversed." Dr Bongiovanni s outstanding work in this field is included in Wilkin s "Endocrine Disorders in Childhood and Adolescence to be published.

Case 93



Case 93, *a* Boy, aged four, with extensive burns of both legs He was referred to the author's service three months after the burn In three skin graft operations both legs and knee joints were covered with autogenous split grafts

b The general condition of the patient, however, deteriorated, hence homogenous split skin grafts (from his father) were used to close all raw surfaces His general condition improved immediately

c The first homogenous graft started to disintegrate two months later. Four more operations were required to close the remaining raw surface with autogenous grafts

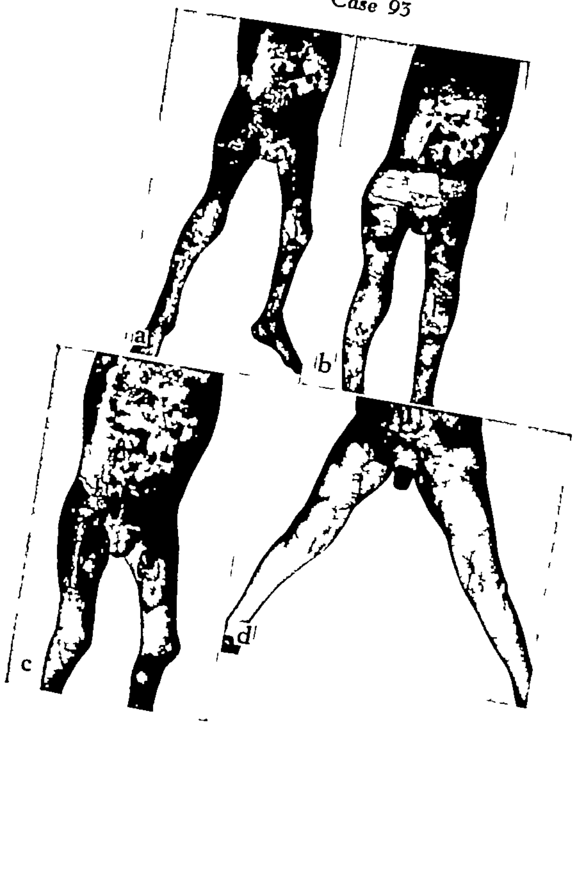
d One year later cicatricial adduction contractures of the groins and thighs were corrected with Z-plasty and skin grafts

Microscopic picture depicts the homogenous skin graft five weeks after transplantation Graft has "taken" well, note absence of any proliferative activity Lower sections show homogenous skin graft in process of sloughing off Extensive fibrous tissue reaction

Case 92

Case 94

Case 93



Case 96

Case 96, *a* Extensive burn of both legs, contracture of both knee joints (patient referred to author for repair six months after the accident).

b The raw surfaces covered with skin grafts, the contracture partly reduced Posterior subluxation of the tibia due to contracture of posterior ligaments and capsules, to be overcome by longitudinal and vertical traction

c, d X-ray pictures of same patient, showing on the left the posterior subluxation of the tibia, on the right the reduction of the subluxation by traction Later, a plaster cast was applied in this position with incorporation of the wires

e, f One year after operation (H May S Clin North America)

Case 94

Case 94 *a* Extensive burns of chest, right shoulder right arm and neck. Shock treatment. Local treatment consisted of pressure dressings The eschar started to come off on the twelfth day It was completely excised on the eighteenth day First skin graft operation on the twenty fourth day *b* Three skin graft operations were required and later on a Z-plasty to overcome a contracture of the right axilla

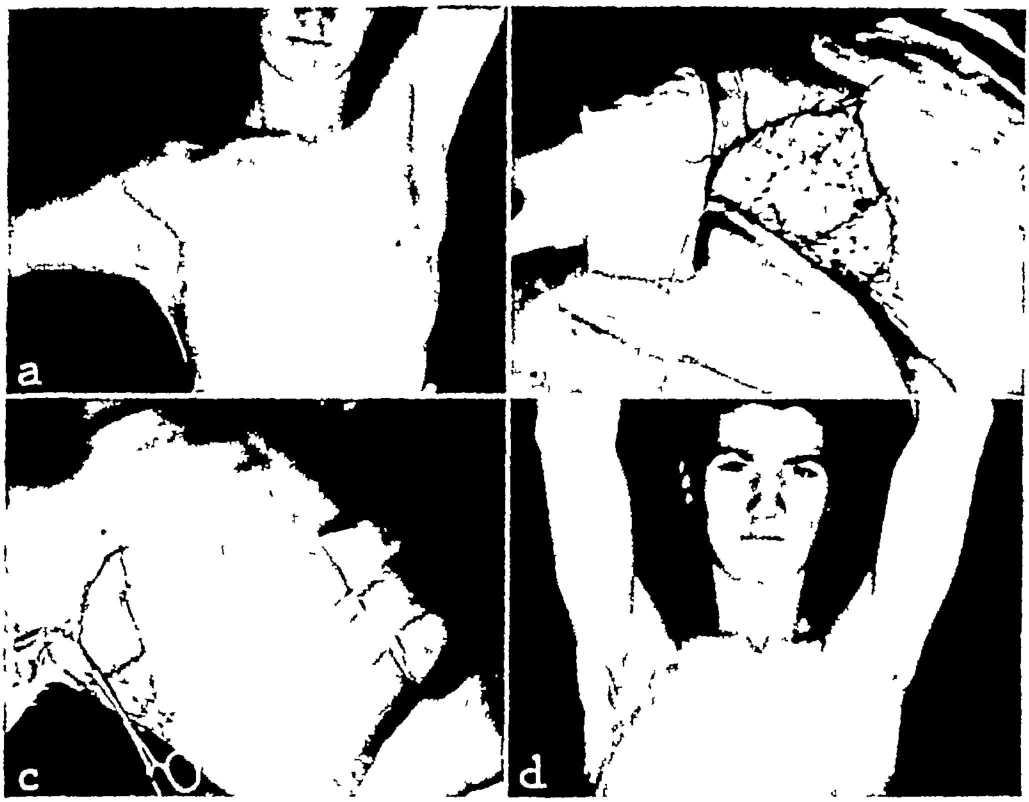
Case 95

Case 95 *a* Posterior view of patient with a binding web of anterior part of axilla after burn.

b Condition corrected by double Z-operation which broke up the binding web and released the contracture (Fig 53 p. 146).

c Patient three months after repair

Case 97



Case 97, *a* Contracture of right axilla from old burn

b Repair similar to that of Case 98 Note probes behind the everted skin

c At the time of the first change of the dressing, the everted skin flap was released

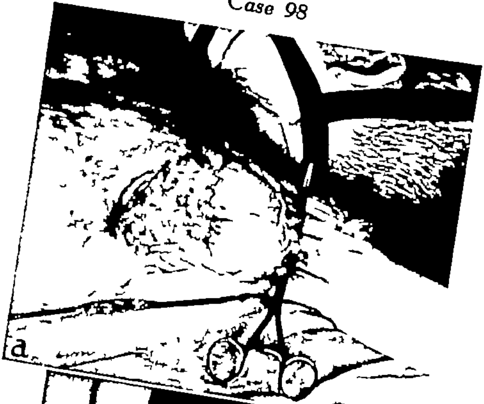
d Result three months later , S Clin North

Case 96

Case 99, *a* Extensive contracture of left axilla from burn

b. The scar was incised near the chest, the contracture reduced, and the defect covered with two skin grafts Result six months after operation.

Case 98



Case 98 *a* Contracture of left axilla from old burn scar Contracting scar was incised the contracture reduced. The lateral wound edge was everted and sutured to the skin of the arm so that skin came to lie on skin (Kelly clamp behind the everted skin) This increased the raw surface to counteract recontracture The defect was covered with two skin grafts *b* After four months.

Case 100

Case 100, *a* Patient, aged sixty-one, with old burn contracture of right axilla An ulcer developed in the scar It was excised The microscopic examination did not show any evidence of malignancy The entire area of the ulcer was excised and skin grafted

b· Eight months later a melanosarcoma developed on the other side of the arm within the burn scar The entire scar and the tumor was excised, i e , practically the entire surface of the right upper arm The axilla was opened from a relaxation incision All axillary glands were dissected Vessels and nerves were covered with flaps from the neighborhood while the remaining raw surfaces were closed with a skin graft

c: Six months after the operation Patient died one and one-quarter years later from metastases

Case 99

Case 100

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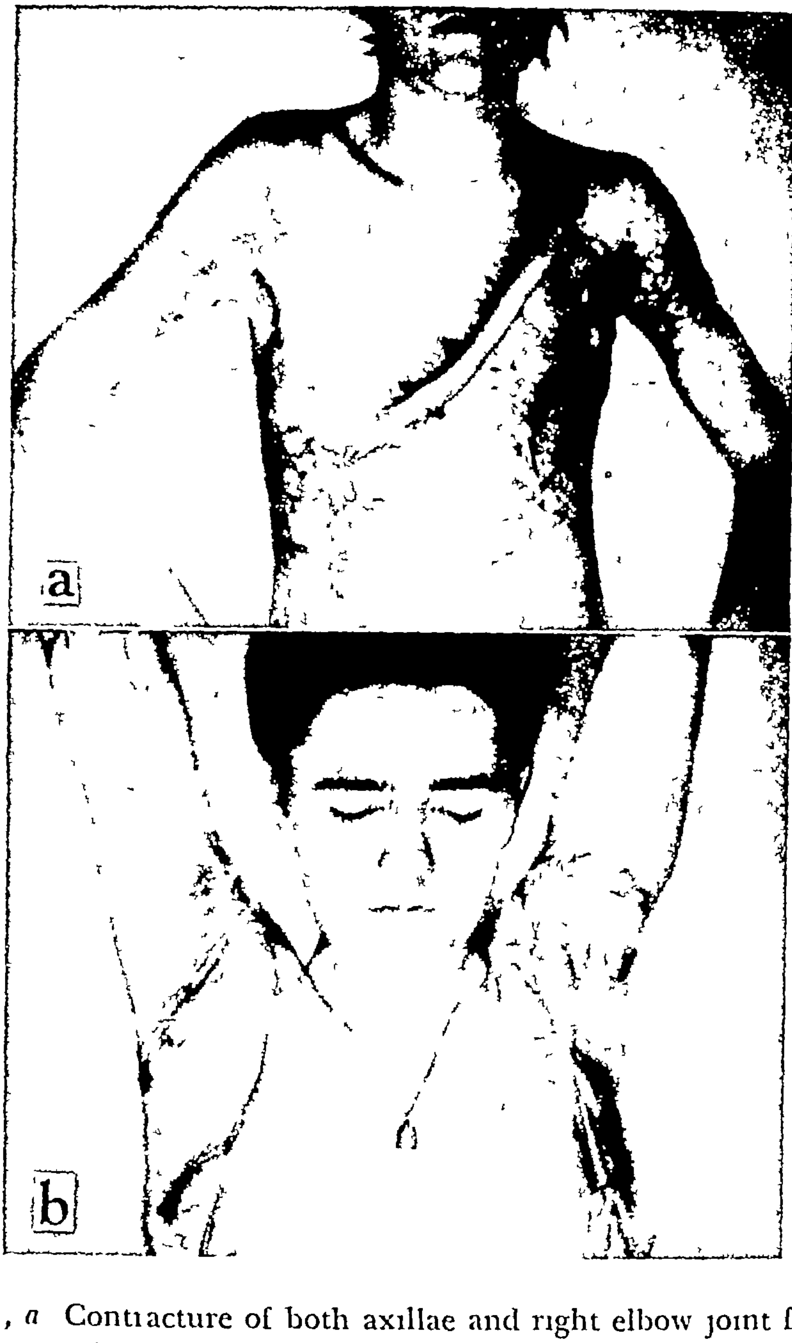
Case 100

Case 101



Case 101, *a* Contracture of both axillae and right elbow joint from burn, normal skin in right axilla An incision was made along the median border of the normal skin at the right side of chest (see dotted line). This part of the skin was undermined and the contracture reduced The defect was covered with one large skin graft A skin-graft repair to overcome the contracture of left axilla was unsuccessful, hence, a tube flap was made from the immediate neighborhood and transplanted in stages The contracture of right elbow joint was repaired by a Z-plastic operation *b* Result four years after operation (H. May S Clin North America)

Case 100

Case 103, *a*. Eight-year-old boy with contracted scar of right elbow joint and axilla from burns Burned area included entire right half of chest and abdomen Contracting scar of right elbow joint was thick and heavy A tube flap was made from left thoracicoepigastric region

b. The lower end of the tube flap was severed after three months, and fastened to the left wrist. The upper pedicle was severed after seventeen days

c The contracting scar at elbow joint was incised, the contracture reduced, and the insertion of the biceps severed (no impairment of function resulted later from severance of biceps insertion) The tube flap was opened and sutured into the defect Both arms are immobilized in a plaster cast.

d· The flap was severed from the wrist after two weeks. Condition three years after repair Note length of flap (x–x) (H May S Clin North America)

Case 102

Case 102, *a* Carcinoma of breast spiral incision for prevention of contracture outlined (p 563) Two opposite points at the extreme parts of the curves outlined by two dots, which facilitate correct approximation of the wound edges later

b After closure of the wound Patient was able to raise the arm without any limitation of motion one week after operation.

Case 104

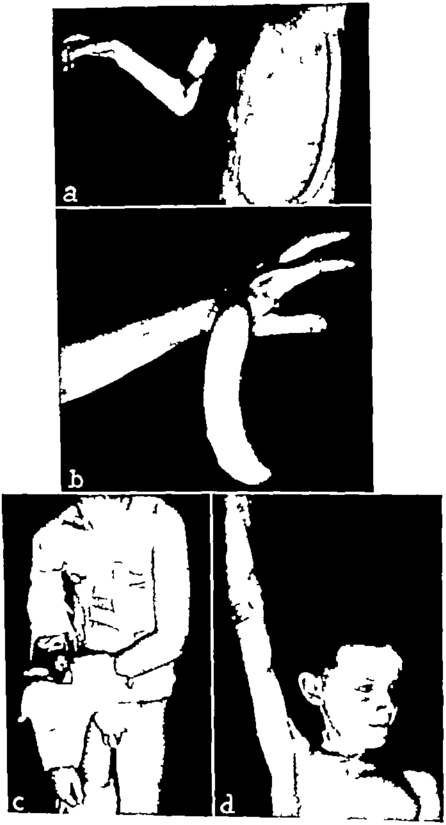
a

b

Case 104, *a* Leg ulcer of long standing Cultures revealed the anaerobic hemolytic streptococcus Extensive contracture of the Achilles tendon. After zinc peroxide treatment for one week, cultures were negative

b· The ulcer was excised, the defect skin-grafted The contracture of the Achilles tendon was overcome by gradually stretching under anesthesia and encasing the extremity in a plaster cast in four sittings, three weeks apart

Case 103

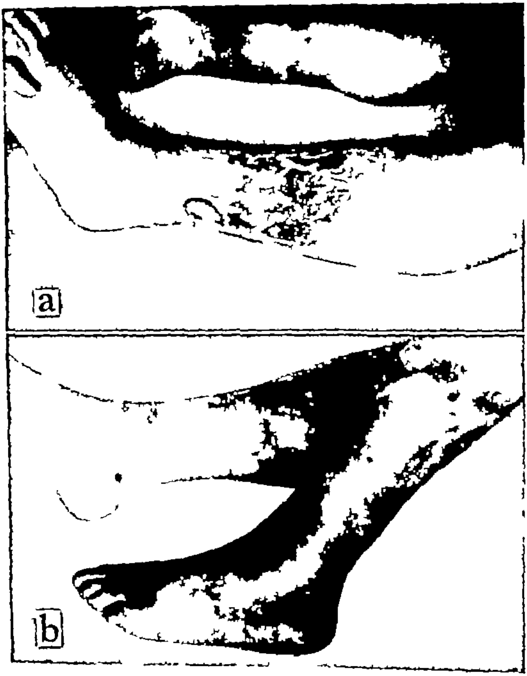


Case 106, *a* Patient, aged sixty-seven, had a large cancer over his shoulder joint and scapula Several attempts with radiation did not allay the growth Wide excision of the area was performed, in which the spine of the scapula was partly removed (to be seen in the center of the wound) and part of the deltoid muscle This defect was to be covered with a tube flap from the abdomen, transferred by means of the left hand

b. The tube flap was constructed in the right thoracoepigastric region. The diagram on the left side points out the way in which the tube flap was closed by staggering. Three and a half months later, the distal pedicle was gradually severed This took seven days

c. Two weeks later, the free end of the flap was fastened to the dorsum of the left hand Two weeks later, the proximal pedicle was gradually severed This took one week

Case 105



Case 105 *a* Patient aged sixty three with bilateral extensive varicose ulcers. After ligation and stripping of varicose veins the right ulcer was widely excised down to the deep fascia and split skin grafts were applied. In a subsequent operation six months later the left ulcer was treated the same way Three years later there were small recurrences of both ulcers hence both ulcers had to be excised again and skin grafted

b Since that time, four years later no evidence of recurrence.